

New Scientist

WEEKLY October 29 - November 4, 2016

PARTICLE PANACEA
A simple solution for five big physics problems

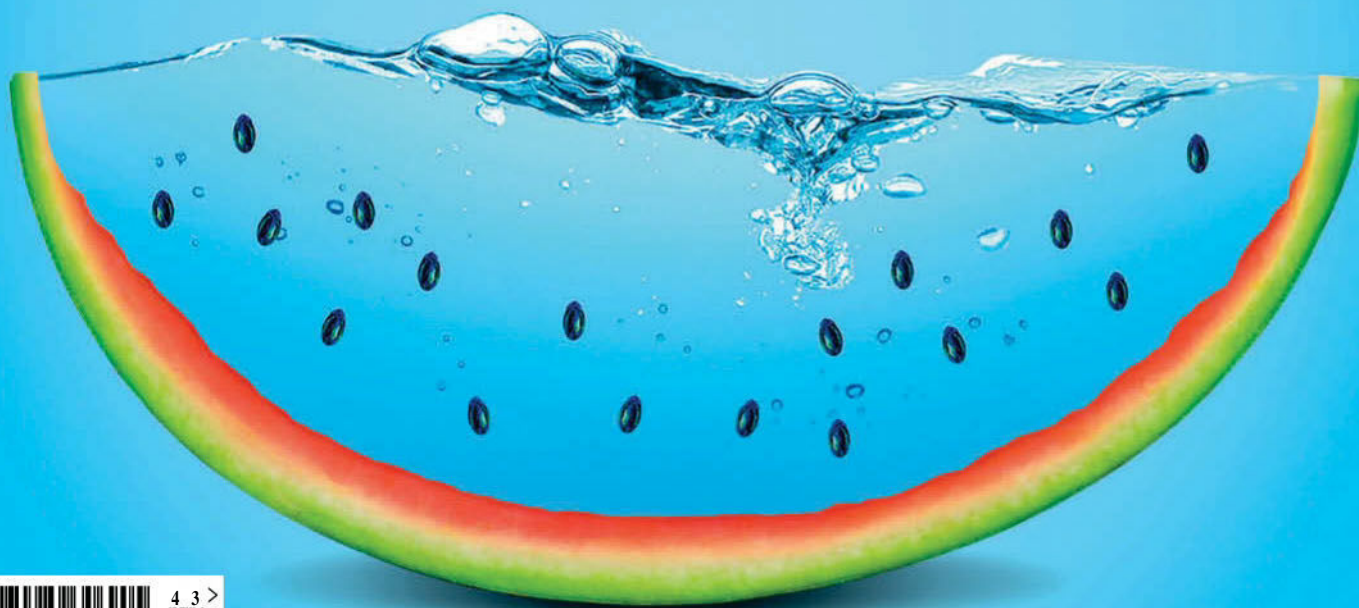
SUPER SMARTS
Brain implants to boost intelligence

DEEPEST HEAT
Iceland's quest to tap volcanoes for power

UNBEARABLE LIKENESS OF BEINGS What makes almost-humans uncanny?

OUR IMPLAUSIBLE UNIVERSE

The more we look at it, the stranger it becomes



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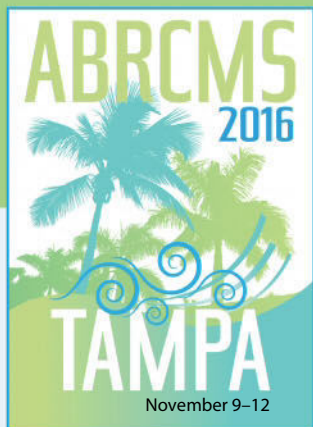
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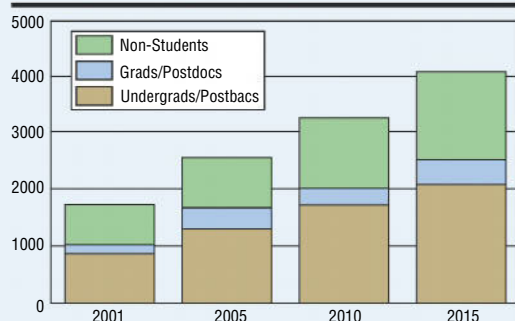
Annual Biomedical Research Conference for Minority Students (ABRCMS)

Tampa Convention Center | Tampa, FL | November 9-12, 2016

ABRCMS advances undergraduates and postbaccalaureates from underrepresented populations, including those with disabilities, in science,

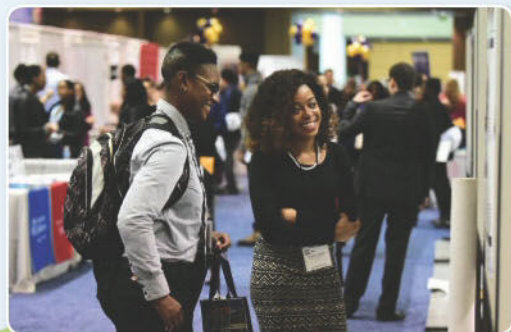
technology, engineering and mathematics (STEM) along the path toward graduate-level training. The conference features about 1,800 poster and oral presentations, along with scientific, professional development, and networking sessions. Approximately 700 exhibitors showcase their summer research and graduate school opportunities.

ABRCMS Registration



"It was a great opportunity to see the extraordinary research being conducted in the country and also to encourage and offer thoughtful advice to the future scientists."

FACULTY/JUDGE

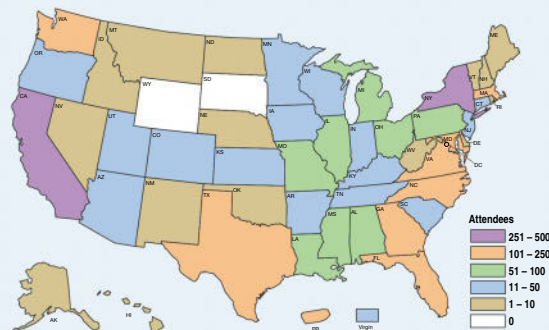


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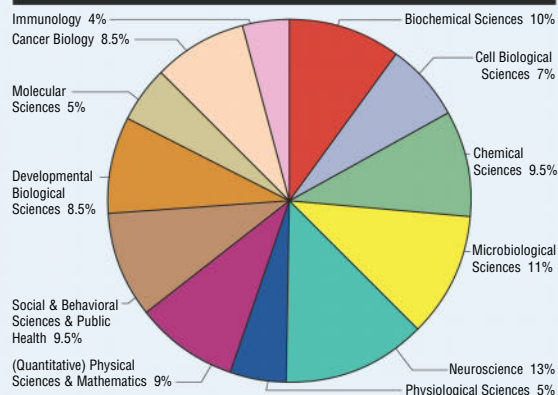
Judges' Travel Subsidy Application:..... July 12, 2016
 Travel Award Application: August 26, 2016
 Abstract Submission: September 9, 2016
 Discount Registration:..... October 12, 2016

For more information, please visit: www.abrcms.org.

2015 ABRCMS Attendees by Location



2015 Distribution of Scientific Disciplines



"I love ABRCMS because of the vast amount of opportunities it has to offer. I meet so many new people who broaden my perspective of different areas of research. It's great to see people from all walks of life who possess the desire to be involved in science."

STUDENT ATTENDEE



ABRCMS is sponsored by National Institute of General Medical Sciences (award number: T36GM073777) and the American Society for Microbiology.



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Long-distance living

Experiencing life in a robot's body on the other side of the world

HIROKUNI MIYATA/CAMERA PRESS



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SIDSNAPPER/GETTY

Man or mouse?

Animal-based drug studies are losing sight of human illnesses

"WE HAVE moved away from studying human disease in humans," said Elias Zerhouni, the former director of the US National Institutes of Health, in 2013. The ability to knock out or insert specific genes in lab animals – mice in particular – has led ever more researchers to shift focus away from people. "The problem is that it hasn't worked, and it's time we stopped dancing around the problem... We need to refocus and adapt new methodologies for use in humans to understand disease biology in humans."

That was three years ago, but little has changed. The latest warning that medical research is barking up the wrong tree comes from Joseph Garner of Stanford University in California (see page 44). Garner is interested in why so few new drugs that get into clinical trials actually make it to market, and says that one important contributor is animal models that do not genuinely model human disease. For example, drug research on cognitive conditions relies heavily on animals that have been genetically manipulated into displaying characteristics that are Parkinson's-like, OCD-like, anxiety-like, autism-like – you name it, there's probably a mouse, or a primate, for it.

Find a way to treat such animals, the conventional thinking goes, and you might discover a treatment that works in humans too. But is what ails the animal also what ails us? Increasingly not, meaning that less and less animal research is benefiting humans. The investment needed to bring a drug to market roughly doubles every decade, partly because of animal models increasingly failing to model human disease. Another problem is the ruthless standardisation of the animals.

"Animal research is only ethically justified when it produces clear benefits for humanity"

That is understandable; it is easier to control for confounding factors when there aren't any. But it drags research animals even further away from representing human populations. Humans aren't all the same, with identical environments and diets. Yet the supposed "models" of our diseases are.

The dangers of excessive standardisation have been known for decades. In 1935, the great mathematical biologist Ronald Fisher pointed out the risks in his seminal book *The Design of Experiments*: "The exact

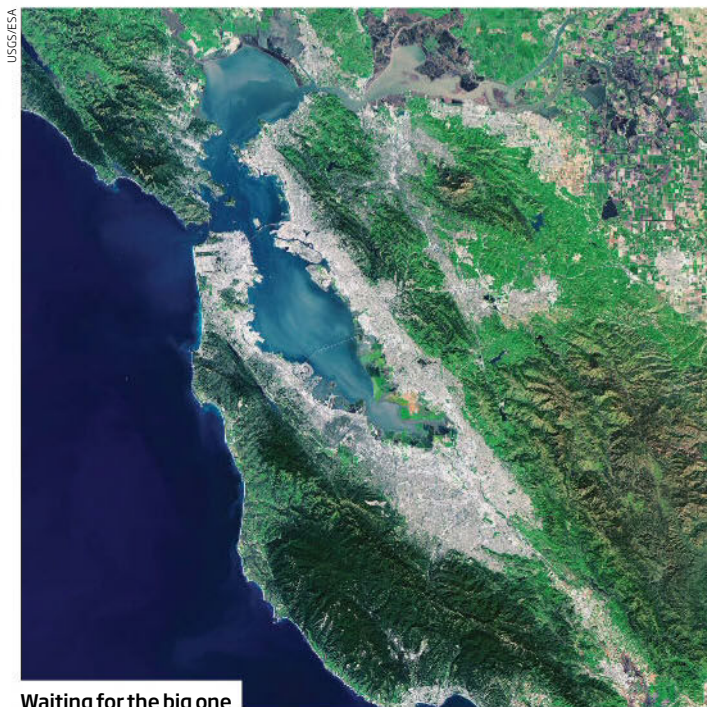
standardisation of experimental conditions, which is often thoughtlessly advocated as a panacea, always carries with it the real disadvantage that a highly standardised experiment supplies direct information only in respect of the narrow range of conditions achieved by standardisation."

One solution is to start performing animal experiments as if they were human trials, with levels of variety that are seen in human populations.

If anything, however, the problem is likely to worsen. The use of genetically altered animals in biomedical research is set to explode because creating them is getting ever easier and cheaper, courtesy of new gene-editing techniques.

If we're not vigilant, ever more public money will be squandered on esoteric research into the unique quirks of genetically modified animals, with little relevance to humans.

That is not fair on taxpayers or the animals themselves. Animal research is only ethically justified when it produces clear benefits for humanity. It is also grossly unfair to those people the research is meant to benefit. As Garner puts it: "Once you start meeting patients, you realise the urgency of getting this right." ■



Waiting for the big one

San Francisco quake fear

A MASSIVE quake could destroy much of the US West Coast, but how big could it get? In the San Francisco Bay Area, new findings show a direct link between two fault lines that could trigger a magnitude-7.4 quake.

It would radiate five times as much energy as the 1989 Loma Prieta earthquake that killed dozens, injured thousands and cost billions of dollars in direct damage. "The concerning thing with the Hayward and Rodgers Creek faults is that they've accumulated enough stress to be released in a major earthquake," says Janet Watt, a geophysicist at the US Geological Survey. "They're, in a sense, primed."

These two faults combined cover 190 kilometres and run parallel to their famous neighbour,

the San Andreas fault, from Santa Rosa in the north to right under Berkeley stadium in the south.

To map the faults, Watt and her team scanned back and forth across the bay for magnetic anomalies that crop up near fault lines. They also swept the bay with a high-frequency acoustic instrument called a chirp to image the faults' relationship below the sea floor using radar and sonar.

The direct link they found makes it easier for a larger earthquake to rupture both faults. The Hayward and Rodgers Creek faults combined could produce an earthquake releasing five times as much energy as the Hayward fault alone. The Hayward fault goes an average of 140 years between quakes, and the last one was 148 years ago.

Crash landing

NEW pockmarks on the surface of Mars seem to be linked to the ExoMars Schiaparelli lander, which was lost shortly before it was supposed to touch down on the planet's surface on 19 October.

"The lander may have exploded on impact, since its thrusters' fuel tanks were probably not empty"

Pictures of the planned Meridiani Planum landing site, taken by NASA's Mars Reconnaissance Orbiter on 20 October, show two marks that weren't visible in May this year.

One mark is bright, and is believed to be associated with the lander's parachute. The other is a larger, darker patch about a kilometre to the north – probably the impact site of the lander itself.

The European Space Agency and Roscosmos mission plan had been for the lander to detach from the parachute about 1 kilometre above the surface, and fire its thrusters to brake its descent

down to 2 metres. It would then fall the remaining distance to plunk down on Mars safely, if not elegantly.

The images suggest that its thrusters switched off prematurely, and it dropped from an altitude of between 2 and 4 kilometres at a speed exceeding 300 kilometres per hour. The lander may have exploded on impact, since its thrusters' fuel tanks were probably not empty.

The Trace Gas Orbiter – the other half of the mission – is still functioning well. It should begin taking scientific data next month.

DNA climbdown

KUWAIT has scaled back a law forcing citizens and visitors to provide DNA samples.

The law, the first of its kind in the world, was ostensibly introduced to combat terrorism. Critics say it is unconstitutional, undermines privacy and that it is unlikely to prevent terrorist attacks.

In the wake of a legal challenge last month and an appeal from the emir of Kuwait, the country's parliament has now agreed to amend the law so that only

suspected criminals will need to provide their DNA. "Public authorities in Kuwait have agreed collectively on the flaws of the current DNA law," says Adel Abdulhadi, the lawyer behind the legal challenge.

The planned amendment has won praise internationally. "This is a wise and responsible decision," said Olaf Rieß, president of the European Society of Human Genetics. "The law as originally proposed would have had negative consequences not just for Kuwaiti society, but also for medical science and research."

In the line of duty

A PROMINENT Antarctic researcher died on 22 October after his snowmobile plunged 30 metres into an unseen crevasse.

Glaciologist Gordon Hamilton from the University of Maine Climate Change Institute in Orono was fatally injured in the fall, said a statement released by the National Science Foundation.

At the time, Hamilton was working with a team from the US Antarctic Program identifying



Gordon Hamilton: crevasse death

and filling in newly formed crevasses along the McMurdo shear zone. Hamilton was using robots equipped with ground-penetrating radar to study the stability of the ice shelves.

"Antarctica's an extremely dangerous environment, and Gordon's work was in a particularly hazardous place," says Martin Siegert at Imperial College London, who has worked for many years in Antarctica, and knew Hamilton well. "He was an outstanding glaciologist, and would have been aware of the risk, and I know of very few people more experienced than him."

Prescription woe

ADDITION to prescribed medicines could be as big a problem in the UK as addiction to illegal drugs like heroin. So say a group of doctors and politicians, who are calling for urgent action to help people who get hooked on painkillers, antidepressants and anti-anxiety medicines.

"We are in the midst of a great public health disaster, which is ruining the lives of millions," Harry Shapiro, head of charity DrugWise, told a meeting of the All Party Parliamentary Group for Prescribed Drug Dependence last week. Doctors at the meeting said addiction clinics focus on helping people abusing illegal drugs or alcohol – so people stuck on prescription meds have nowhere to turn for support.

The number of prescriptions for painkilling opioids has soared in the UK, as it has in the US. But the two epidemics have different causes, says Cathy Stannard at Southmead Hospital in Bristol, UK. Many people in the US use painkillers to get high, while most people in the UK use them for medical reasons, she says.

The British Medical Association has called for a dedicated National Health Service helpline and website to advise people hooked on prescription drugs.

Botnet attack

LAST weekend, bots besieged the web. Popular internet sites including Twitter, Paypal and Reddit were knocked offline during a huge attack.

The distributed denial of service (DDoS) attack was made by a botnet formed of hundreds of thousands of computers and "internet-of-things" devices. Hackers used them to launch a barrage of traffic at internet infrastructure company Dyn.

Devices made by Chinese firm Hangzhou Xiongmai Technology were identified as being among

those targeted by the hackers, and the company announced on Monday that it would recall some US products. It said one issue was that users hadn't changed their passwords from the factory-set defaults – but some researchers say it isn't possible for a user to change all the credentials on some models.

"It's really not rocket science to build something into these devices so that the first time they're used, you have to change the username and password," says Alan Woodward, a computer scientist at the University of Surrey in Guildford, UK.

450 snow leopards killed a year

AS MANY as 450 endangered snow leopards have been killed every year since 2008, according to a report on the fate of the mountain cats.

Only 4000 to 7000 of the animals are thought to remain in the 12 mountainous Asian countries they inhabit. A big surprise is that herders are responsible for more than half the killings – 55 per cent – in revenge for leopards attacking their livestock, with only 21 per cent of the cats taken by poachers.

"It's a completely new insight, and provides a very important point for discussion on how to ensure snow leopards are protected," says Rishi Sharma, leader of the snow leopard programme at wildlife charity WWF. Sharma is a co-author of the new

report by TRAFFIC, a global organisation that monitors the illegal trade in endangered species. The study used government data and interviews with local leopard experts.

"More than half the killing is not for illegal trade as such, so as long as we don't address these issues affecting local communities, it will continue," warns Sharma. He adds that the insight offers potential ways to address the problem. First, he says, governments in the 12 countries across the leopard's range should increase the funds available to compensate herders whose animals are killed. Second, herders should be given extra materials to strengthen the pens where they keep their animals at night.

TESSA MCGREGOR



A heavy toll

60 SECONDS

Footie fallout

Strikers beware – heading a football alters brain function straight away. A study of 19 footballers who each headed a ball 20 times showed immediate changes to brain activity and falls of up to 67 per cent in memory test scores (*EBioMedicine*, doi.org/br7h). Although both reverted to normal within 24 hours, the repetitive impact may have consequences for brain health.

Grim threshold reached

In 2015, atmospheric carbon dioxide averaged 400 parts per million across the globe throughout the year, for the first time. Levels will not fall below this symbolic threshold for many generations, which marks "a new era of climate change reality", said the World Meteorological Organization's secretary general Petteri Taalas on Monday.

Download complete

The New Horizons probe flew past Pluto in July 2015, but has only just finished showing us what it found. The probe has been streaming data back ever since its fly-by, the last packet should arrive on 25 October.

No haven for whales

Hopes for a new whale sanctuary in the South Atlantic fell through this week when the vote on its creation failed to get the required three-quarters majority at the International Whaling Commission meeting in Slovenia. The sanctuary would have banned commercial hunting within its waters.

Did you hear the one...

...about the creature with 414 legs, 200 poison glands and four penises? It's not a joke. A new species of millipede, *Illacme tobini*, discovered in Sequoia National Park in California has just these anatomical features. A single specimen of its relative *Illacme plenipes* holds the world record for having the greatest number of legs: 750 (*ZooKeys*, doi.org/br77).

Being in a robot's shoes

Transplanting ourselves into a distant robot isn't as hard as you'd think

Helen Thomson

IN THE 2009 Bruce Willis movie *Surrogates*, people live their lives by embodying themselves as robots. They meet people, go to work, even fall in love, all without leaving the comfort of their own home. Now, for the first time, three people with severe spinal injuries have taken the first steps towards that vision by controlling a robot thousands of kilometres away, using thought alone.

The idea is that people with spinal injuries will be able to use robot bodies to interact with the world. It is part of the European Union-backed VERE project, which aims to dissolve the boundary between the human body and a surrogate, giving people the illusion that their surrogate is in fact their own body.

In 2012, an international team went some way to achieving this by taking fMRI scans of the brains of volunteers while they thought

"The feeling of embodying the robot was good, although the sensation varied over time"

about moving their hands or legs. The scanner measured changes in blood flow to the brain area responsible for such thoughts. An algorithm then passed these on as instructions to a robot.

The volunteers could see what the robot was looking at via a head-mounted display. When they thought about moving their left or right hand, the robot moved 30 degrees to the left or right. Imagining moving their legs made the robot walk forward.

Now, a second team has tested a similar set-up in people who are paralysed from the neck or trunk down. To make the technology

cheaper, more comfortable and more portable, the team swapped the fMRI scanner for an electroencephalogram (EEG) cap, which records electrical activity in the brain using electrodes attached to the scalp.

Each of the three volunteers in Italy donned the cap plus a head-mounted display that showed what a robot – in a lab in Tsukuba, Japan – was looking at. To move the robot, they had to concentrate on arrows superimposed across the display, each flashing at a different frequency. A computer could detect which arrow a participant was staring at using the EEG readings that each frequency provoked. It then sent

the corresponding movement to the robot.

The set-up allowed the volunteers to control the robot in near real time. They were able to pick up a drink, move across the room and put the drink on a table. "It took just 6 minutes of training to start using the technology," says Emmanuele Tidoni at the University of Rome. "The feeling of actually embodying the robot was good, although needless to say, the sensation varied over time," said Alessandro, one of the volunteers living with spinal cord injury. "When the robot was stationary the feeling of embodiment was low, but the moment I gave the first command

or changed direction, there was this feeling of control and increased embodiment."

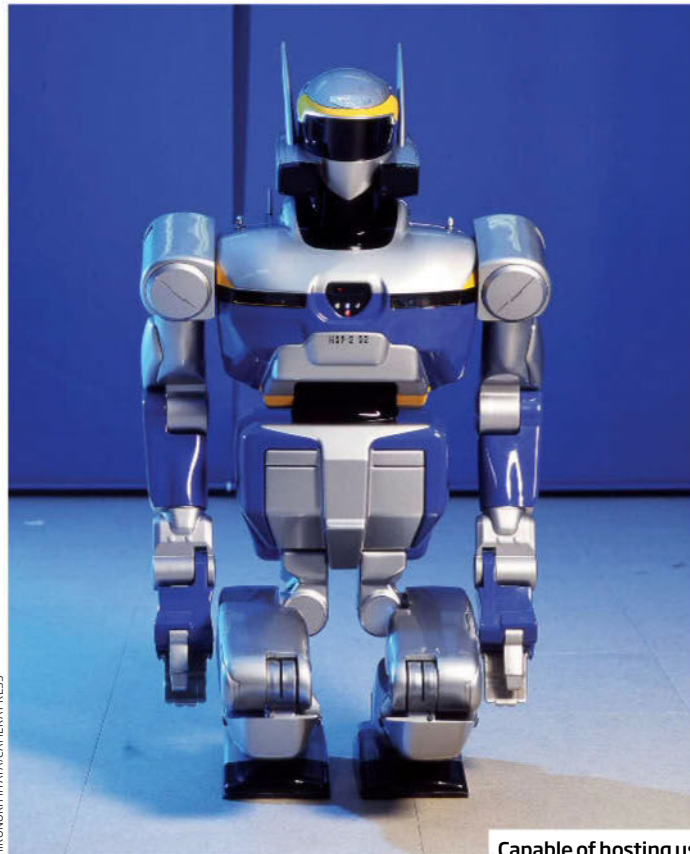
The team also tried to boost this feeling using auditory feedback. While controlling the robot, both able-bodied volunteers and people with spinal cord injury managed to place a bottle closer to a target location when they heard footsteps as they walked, rather than a beep or no noise at all. The improved control suggests they feel more in tune with the robot itself, says Tidoni.

The project also studied how this technology could be used in social interactions, by getting people in Italy to play a chess-like game via the robot against an opponent located in Munich, Germany. The results will be published later this year.

Alessandro is excited about the potential. "It's a sensitive and important issue, but will certainly have a major impact on the way we all can communicate to each other," he says.

But he hopes that the implications for mental health will also be looked at. "What will happen to a person who cannot move in real life after they use this technology intensively? Will they still feel isolated or lonely?" he asks. "Any developments also need to study the impact that these technologies may have on the psychological well-being of people with various degrees of disability."

Although we're not yet at *Surrogates*-level immersion, the technology could one day dramatically improve the lives of people with paralysis, says Noel Sharkey at the University of Sheffield, UK. "This is a very long way off, but getting towards that for people who otherwise can't move would be astounding." ■

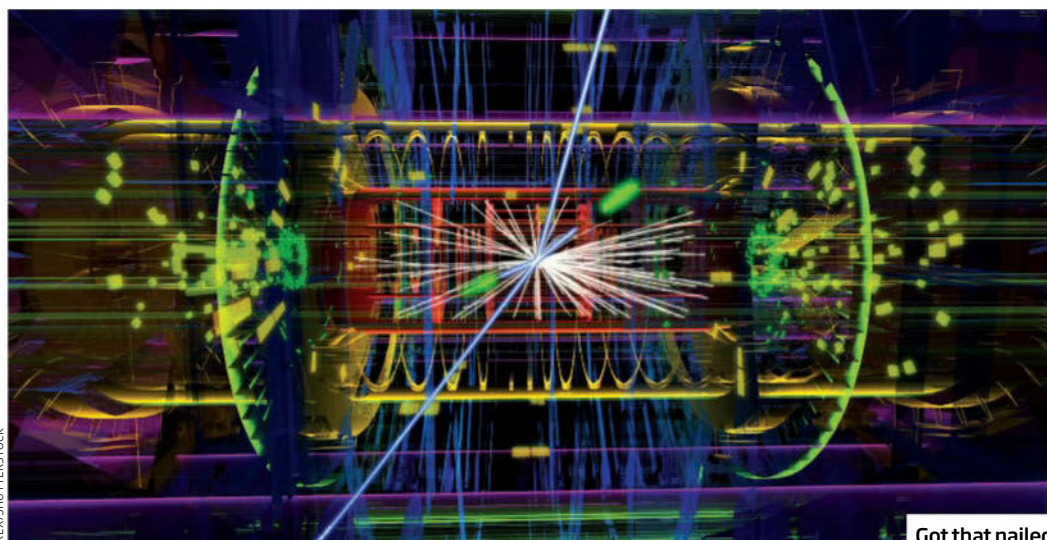


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Got that nailed

Theory tweak solves five physics problems at once

IT'S not a bad day at work. Five of the biggest fundamental problems in physics seem sorted in one go. The model that can do this, formulated by Guillermo Ballesteros at the University of Paris-Saclay in France and his colleagues, may explain dark matter, neutrino oscillations, baryogenesis, inflation and the strong CP problem.

Dubbed SMASH, the model is based on the standard model of particle physics, but has a few bits tacked on. The standard model is a collection of particles and forces

that describes the building blocks of the universe. Although it has passed every test thrown at it, it can't explain some phenomena. For example, we don't understand dark matter, the mysterious substance that makes up 84 per cent of the universe's mass. Nor why there is more matter than antimatter. Nor why the universe grew so rapidly in its youth during a period known as inflation. The list continues.

So something is still missing from the standard model. "Presumably we need some

new particles," says Mikhail Shaposhnikov at the Swiss Federal Institute of Technology in Lausanne. "The question is, how many new particles do we need?"

Some models, like supersymmetry, add hundreds of particles – none of which have been spotted at colliders like the LHC. But SMASH adds only six: three neutrinos, a fermion and a field that includes two particles.

SMASH is several theories smashed together, says co-author Andreas Ringwald at the German Electron Synchrotron, DESY, in Hamburg. It builds on Shaposhnikov's model from 2005, which added three neutrinos to the three already known in order to solve four fundamental

problems in physics: dark matter, inflation, some questions about the nature of neutrinos, and the origins of matter.

SMASH adds a new field to explain some of those problems a little differently. This field includes two particles: the axion, a dark horse candidate for dark matter, and the inflaton, the particle behind inflation.

As a final flourish, SMASH uses the field to introduce the solution to a fifth puzzle: the strong CP problem, which helps explain why there is more matter than antimatter in the universe.

"The best thing about the theory is that it can be tested or checked within the next 10 years or so," Ringwald says. "You can always invent new theories, but if they can only be tested in 100 years, or never, then this is not real science but meta-science."

SMASH predicts that the axion should be about ten billion times lighter than the electron. Particles this small could be probed by the CULTASK experiment running in South Korea, or the proposed ORPHEUS experiment in the US and the planned MADMAX experiment in Germany.

This doesn't mean it's game over. It's more like game on. Physicists will continue to compete to find experimental evidence or a better model. "The battle is open," Ringwald says. **Shannon Hall ■**

Cashmere galore from gene-edited goats

WHO doesn't like cashmere? In a few years' time, those wonderfully soft sweaters people buy could come from gene-edited goats. A team in China has created goats that produce a third more cashmere than standard goats.

The researchers at the Shanbei Cashmere Goat Farm of Yulin University used the CRISPR gene-editing technique to disable the *FGF5*

gene, which limits hair growth, in the Shanbei breed of cashmere goats. *FGF5* controls hair length in a variety of animals, including humans. For instance, a few people have unusually long eyelashes because of mutations in the gene. The long hair in some breeds of animals, such as Pembroke Welsh corgis, is also due to similar mutations.

The edited kids were born a year ago and now the team has studied six of them in detail. As hoped, disabling *FGF5* increased the length of both their coarse outer hair and their softer inner hair. The inner hair remained as

fine as normal, which is crucial because the thinness of these fibres is the key to soft cashmere wool (*PLoS One*, doi.org/br6s).

The team has already managed to breed the goats. "The offspring of the edited goats are four months old, and growing normally," says team member Xiaolong Wang at Northwest A&F University in Yangling. If the project succeeds in producing lots of

"China is the world's top producer of cashmere wool, so we could soon see this on the market"

high-yielding cashmere goats, some of China's cashmere – it is the world's largest producer – could soon come from gene-edited goats.

It's not clear if cashmere from these animals will be kept separate or treated any differently from standard cashmere, but there is no obvious reason why it should be. Creators of gene-edited animals argue that when gene editing is used to introduce mutations that occur naturally, the resulting breeds should not be subject to the regulations that apply to genetically modified organisms.

Michael Le Page ■



Untapped energy promise

Iceland drills deep for magma's heat

Fred Pearce

DRILLING into hot rocks to tap geothermal energy is one thing. Drilling deep enough to tap the blazing heat from magma oozing into volcanoes is quite another, offering a huge increase in the potential to exploit Earth's energy.

That is the task of a rig now drilling 5 kilometres into the rugged landscape of old lava flows in Reykjanes, at the south-west corner of Iceland. Drilling began on 12 August. By the end of the year, the Iceland Deep Drilling Project hopes to have created the hottest hole in the world, hitting temperatures anywhere between 400 and 1000 °C.

The drilling will penetrate a landward extension of the Mid-Atlantic ridge – a major boundary between Earth's tectonic plates – says Albert Albertsson of HS Orka, an Icelandic geothermal-energy company involved in the project. At that depth, magma rising because of volcanic activity meets and heats seawater that has infiltrated the rock.

"People have drilled into hard rock at this depth, but never before into a fluid system like this," says Albertsson.

At that depth, pressures are more than 200 times atmospheric levels. The consortium of energy companies and researchers behind the project expects the water to be in the form of "supercritical steam", which is neither liquid nor gas and holds much more heat than either.

"A well that can tap into the intense heat of supercritical steam could power 50,000 homes"

A well that can tap into such steam would have an energy capacity of 50 megawatts, compared with the 5 MW of a typical geothermal well, says Albertsson. It could power some 50,000 rather than 5000 homes.

The drilling project unexpectedly struck magma in the Krafla geothermal field of north-east Iceland in 2009. The hot magma was briefly used to

heat water sent down the well to test how much energy could be generated. It never supplied power to the grid, but until it was shut down after corrosion problems, it was the most powerful geothermal well ever drilled, generating 30 MW. This time, the plan is to create a long-term energy source.

"If they can get supercritical steam in deep boreholes, that will make an order of magnitude difference to the amount of geothermal energy the wells can produce," says Arnar Guðmundsson of Invest in Iceland, a government agency promoting energy development.

All of Iceland's electricity already comes from renewable sources such as hydropower and geothermal energy. Hydropower currently generates three-quarters of it, but magma wells could radically change this.

There could be global benefits too, if the technique is adopted elsewhere. "Potential sites for supercritical geothermal resources occur worldwide, where young volcanoes occur," says Wilfred Elders, a geologist at the University of California, Riverside, who is a long-term collaborator on the project. ■ Fred Pearce travelled to Iceland courtesy of Verne Global

Mice fall for body illusions just like us

IT'S a tale of two tails. Mice can be tricked into thinking fake tails are their own, using the same "rubber hand illusion" that works in people. The illusion helps us understand how our brains create a sense of body ownership and awareness. The discovery that mice fall for the same trick could aid the development of prosthetic limbs and treatments for psychiatric disorders.

In the human version of the trick, a person sits next to a rubber hand and their own hand is hidden. Stroking both hands at the same time tricks the person into feeling that the rubber limb is their own. When the fake hand is attacked, people yell out in fear – as if their own limb were under threat.

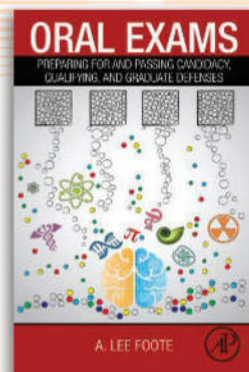
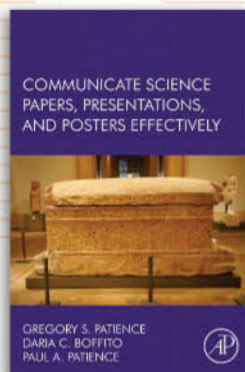
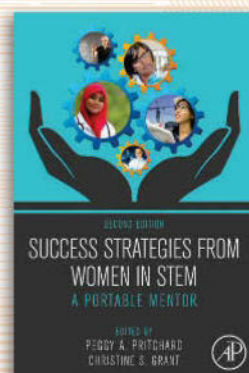
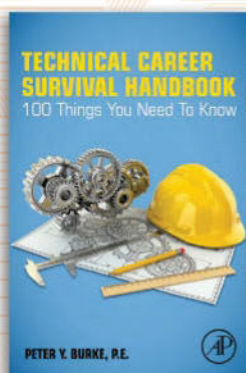
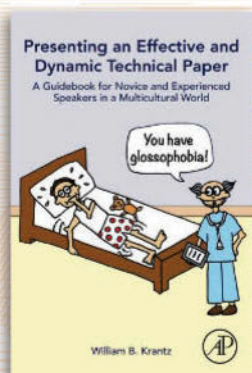
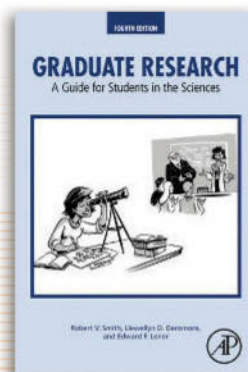
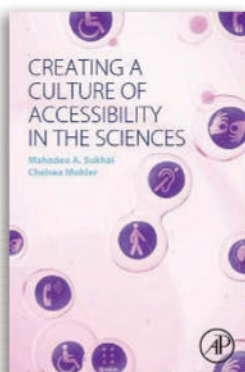
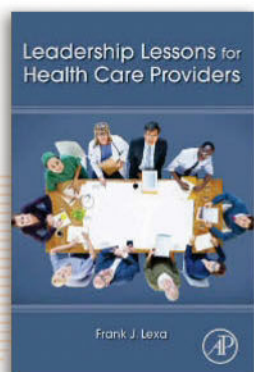
Kenji Kansaku at the National Rehabilitation Center for Persons with Disabilities in Tokorozawa, Japan, and his colleagues performed the same trick on mice, hiding their tails and using a fake one.

When the fake and real tails were stroked out of sync, the mice didn't react to the fake tails being approached. But when their own tail was stroked simultaneously with the fake one, they reacted strongly, twisting as if to pull the fake tail away (*Journal of Neuroscience*, DOI: 10.1523/jneurosci.3006-15.2016).

Henrik Ehrsson at the Karolinska Institute in Stockholm, Sweden, was surprised by the result. In people, a brain region called the parietal association cortex is important for body ownership. This region is tiny in mouse brains, he says.

Studying the activity of various brain cells in mice during the illusion – something you can't do in humans – could offer plenty of insights, says Ehrsson. For example, knowing the precise brain activity involved could shed light on disorders in which body awareness is disrupted, such as schizophrenia, and help with the development of prosthetic limbs that are more easily incorporated into body image. Jessica Hamzelou ■

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Brain implant to boost intelligence

Jessica Hamzelou

IF YOU could implant a device in your brain to enhance your memory and intelligence, would you? A new firm is investing \$100 million to develop such a gadget, and is being advised by some of the biggest names in science.

The company, Kernel, was launched earlier this year by entrepreneur Bryan Johnson. Its first experiments are on memory. Johnson is working with Theodore Berger at the University of Southern California in Los Angeles, who is looking at the hippocampus, a key brain region for memory.

Berger is studying people who already have electrical implants in their brains to treat epileptic seizures. But rather than using the implants to stimulate the brain, Berger's team has been harnessing them to record brain activity, to learn more about how our memory works.

Once we know how a healthy brain functions, we should be able to mimic it, says Johnson. By electrically stimulating the same pattern of activity, the goal is to restore function in people with

memory disorders. Berger has had some success with animals, and has begun experiments in people.

"The idea is that if you have loss of memory function, then you could build a prosthetic for the hippocampus that would help restore the circuitry, and

restore memory," says Johnson.

People with memory disorders will be the first to try the device. "The first potential superhumans are those who have deficits to start with," says Johnson.

He then plans to develop the prosthesis to enhance memory, and potentially other functions, in healthy people. He envisions a future in which it is normal for people to walk around with chips in their brains, providing them with a cognitive boost.

The \$100 million – from

Johnson's own pocket – will go on developing such a device. Ideally, it will be as tiny and easy to implant as possible, while still being able to record or stimulate multiple neurons. The team is also working on ways to develop rules that underlie patterns of activity that dictate normal brain function for an individual.

"If we can mimic the natural function of the brain, then I posit the question, what can't we do?" says Johnson. "Could we learn a thousand times faster? Could we choose which memories to keep and which to get rid of? Could we have a connection with our computers?"

Johnson has some big names advising him, including neuroengineer Ed Boyden at the Massachusetts Institute of Technology, and Craig Venter, who has created synthetic life.

"They too believe we are at a special point in neuroscience," says Johnson. "I think that human intelligence will be one of the largest industries, if not the largest industry, to ever emerge."

But others are sceptical. Neil Burgess at University College London says that even if the team manages to record the activity of neurons in normal memory processing, it will still be hard to find out which bits to turn up and which to dampen down to enhance the process. "I can't see it working," he says. ■



Stimulating idea

Microbe makes a virus to fight a giant virus

A VORACIOUS marine predator plagued by a giant virus has a defence system we've never seen before – it fights back by making its very own virus. The individuals that make these bioweapons sacrifice themselves to save their fellow predators.

The single-celled predator, *Cafeteria roenbergensis*, swims in coastal waters catching bacteria. But

Cafeteria has a deadly enemy of its own, the giant CroV virus.

Most viruses are little more than a protein shell encapsulating a handful of genes. They depend entirely on the machinery of the cells they infect to make more copies of themselves.

But giant viruses, discovered only in 2003, are more like living cells than normal viruses. They have the machinery to make proteins, which means they are vulnerable to viral attack themselves.

For example, maverick viruses infect CroVs, forcing them to make more maverick viruses instead of CroVs, Matthias

Fischer, now at the Max Planck Institute in Germany, found in 2011.

Cafeteria has evolved to exploit this. It carries the genes coding for maverick viruses inside its genome. These genes are usually dormant but they get turned on when *Cafeteria* is invaded by CroV. "It acts as an inducible antiviral defence system," write Fischer and his colleague Thomas Hackl (*Biorxiv*, doi.org/br7f).

"The unique defence strategy means individual cells sacrifice themselves to save their fellows"

The infected *Cafeteria* cell still dies – but when it breaks apart it releases maverick viruses rather than CroVs, preventing the spread of the infection. This, then, is altruistic, a surprisingly common behaviour among microbes. For instance, some bacteria kill themselves as soon as they are infected by viruses to prevent the infection spreading.

A wide range of animals harbour genetic elements that resemble the maverick virus genes, so it's possible some of these organisms can also unleash viruses that kill giant viruses.

Michael Le Page ■

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Language mutation messes up mouse love songs

MOUSE squeaks have more in common with our speech than you think. Tinkering with a gene linked to human language seems to muck up mouse mating calls.

The gene, called *FOXP2*, becomes active in our brains from the womb. There have been two main mutations in the gene since we split from our closest living relatives, chimpanzees, and these are thought to be behind our superior vocal abilities. But some people have a further mutation that causes problems such as difficulty making certain mouth movements and complex sounds.

To find out how this mutation affects speech,

Simon Fisher at the Max Planck Institute for Psycholinguistics in Nijmegen, the Netherlands, and his colleagues gave it to mice and studied how it affected their courting songs: complex sequences of rapid chirps that swoop up and down in pitch and last tens of seconds.

Fisher's team discovered that their songs were shorter and simpler than those of unaltered mice (*Frontiers in Behavioral Neuroscience*, doi.org/br45). "We found properties that are strikingly reminiscent of some of the key features of the human *FOXP2* disorder," he says.

In other studies, giving mice the normal human version of *FOXP2* seemed to make them better at learning to do tasks automatically. This hints that the gene helps infants learn to talk by giving them unconscious control over their lips and tongue.

Brains become desensitised to lying

LITTLE white lies have a tendency to snowball. The more we lie, the more our brains seem to become desensitised to deception.

Tali Sharot at University College London and her team ran an experiment that encouraged volunteers to lie. They were shown jars of pennies, full to varying degrees, and asked to send estimates of how many there were to partners in another room.

The partners were shown blurrier images of the jars, so relied on the volunteers' estimates to guess the number of pennies, in order to win a reward for each of them.

When the volunteers were told they would get a higher personal reward if their partner's answer were wrong – and that the more inaccurate the answer, the greater the reward would be – they started telling small lies, which escalated.

A person who might have started with a lie that earned them £1 may have ended up telling fibs worth £8, for example.

Brain scans showed that the first lie was associated with a burst of activity in the amygdalae, areas involved in emotional responses. But this activity lessened as the lies progressed (*Nature Neuroscience*, DOI: 10.1038/nn.4426). "This highlights the danger of engaging in small acts of dishonesty," says Sharot.

3D-printed material shrinks in the heat

MOST materials swell when they warm up, creating engineering headaches. Now, a 3D-printed material has been configured to contract instead.

When two interlinked materials expand at different rates, they warp or crack. It's a problem in everything from bridges to dental fillings, so getting them to shrink instead of swell as they heat up is a much-prized goal.

Now Qiming Wang at the University of Southern California in Los Angeles and his colleagues have done just that. Using a 3D printer, they took two materials that expand at different rates as they warm and arranged them in a loose matrix where the one that swells faster is inside the other.

When heated, the inner material can only expand inward, pulling the outer material with it. As a result, the whole thing shrinks (*Physical Review Letters*, doi.org/br6r).

Poisonous clouds may form on Pluto

PLUTO may have partly cloudy, noxious skies.

When the New Horizons probe passed Pluto last year, it showed a hazy yet nearly cloud-free world.

Now the team has presented images of seven wispy features, a few kilometres long, that hide the surface below them.

"They're quite suggestive" of clouds, mission leader Alan Stern at the Southwest Research Institute in Boulder, Colorado, told a planetary sciences meeting in Pasadena, California, on 18 October.

Models indicate that any clouds are likely to be made of trace atmospheric ingredients such as hydrogen cyanide, acetylene and ethane. On Earth, these are toxic liquids and flammable gases.

'Boom star' may be rare red nova

A DIM binary star may be on course to explode as a "red nova" in about 2022. If that happens, it could shine as brightly as the North Star.

Dozens of ordinary novae – the temporary flare-ups of white dwarf stars stealing gas from companion stars – explode in our galaxy every year. These novae turn blue.

In recent years, however, astronomers have discovered a rare type of nova that turns red instead. Observations made before a red nova in 2008 revealed that the blast happened when two stars orbiting each other merged into one.

And it now seems that another binary star, named KIC 9832227, could be about to explode as a red nova. "My colleagues like to call it the 'boom star'," says Larry Molnar at Calvin College in Grand Rapids, Michigan.

Observations over the last three years have shown two things about KIC 9832227 that suggest an explosion is imminent. The time it takes for the two stars to orbit each other is decreasing, and it is doing so at an ever-faster rate – as with the 2008 red nova. "A stellar merger is a real possibility," says Alexander Kurtenkov at the University of Sofia, Bulgaria.

The latest observations put the date of the potential explosion between 2021 and 2023, and it could be easily visible to the naked eye.



Lab rats use hooked tools and rakes to reach chocolate cereal

SOME rodents have a sweet tooth. And sometimes they need to be crafty to get their sugar fix.

Rats may have the right idea: they have been filmed for the first time using tools, such as hooks and rakes, helping them to reach a chocolate cereal treat. The feat is a manifestation of their critter intelligence and gets them into a rather exclusive club of tool users.

Akane Nagano and Kenjiro Aoyama, at Doshisha University in Kyotanabe, Japan, trained eight common, brown rats to pull small hooked tools to obtain cereal that

was otherwise beyond their reach.

In one experiment, they gave the rats two similar tools, just one of which worked well for food retrieval. The rodents quickly learned to choose the correct tool for the job, selecting it 95 per cent of the time (*Animal Cognition*, doi.org/br48).

The experiments showed that the rats understood the spatial arrangement between the food and the tool, and that some tools are functional and others are not. The study is the first to demonstrate that rats

can use tools, says Nagano.

The rats became a little confused in the final experiment, though. When the team gave them a rake that looked the part, but with a bottom that was too soft and flimsy to move the cereal, they tried to use it just the same.

However, it is possible that their eyesight was simply not good enough to tell whether the tools were up to the task, says Nagano.

The rodents' crafty feat places them in the ever-growing club of known tool-using animals, which includes chimps and crows.

Smell of mice in pain is infectious

DO others make you feel their pain? Experiments in mice seem to show that sensitivity to pain can be transferred socially.

"We've shown for the first time that you don't need an injury or inflammation to develop a pain state," says Andrey Ryabinin at Oregon Health and Science University in Portland. "Pain can develop simply because of social cues."

Ryabinin's team subjected addicted mice to alcohol or heroin withdrawal. Later, these mice and other, unaffected "bystander" mice kept in the same room had developed hypersensitivity to pain – measured by techniques like dipping their tails in warm water.

"The scores for the bystanders completely matched those of the experimental animals," says Ryabinin.

Further tests found that the trigger for this infectious hypersensitivity is an odour secreted by the mice in pain (*Science Advances*, doi.org/br46). Ryabinin speculates that the phenomenon may have evolved to warn companion animals of impending hazards, diseases or threats.



Sedges, not cereals, fed first settlers

WHEN ancient hunter-gatherers first began to give up their nomadic life, it wasn't necessarily to chase harvests of grain. If so, the transition to sedentary life and agriculture may have been more complex and varied than we thought.

The evidence for this comes from one of the oldest-known sites of long-term habitation, called Kharaneh IV, in Jordan. Environmental archaeologist Monica Ramsey, at the University of Toronto, Canada, and her colleagues studied phytoliths – microscopic silica crystals that form in plant tissues – from the site.

To their surprise, they found few phytoliths from cereals. Instead, the vast majority came from wetland plants such as sedges. Their edible roots yield fewer calories than grains after taking the effort of processing into account, but they are available year-round, and in dry as well as wet years (*PLoS One*, doi.org/br42).

Kharaneh IV was first inhabited some 22,000 years ago. Ramsey suggests people in the area settled there to spend longer near its wetlands and take advantage of the sedges. This gave them the security to start experimenting with cereals.

Invisible killer

Cities are battling to meet legal standards for air pollution, but even that isn't enough to make air safe to breathe, says **Michael Le Page**

WHEN you hear “air pollution”, you probably think of the brown pall of soot that hangs over so many Asian cities. But if you travel on, work or live near a busy road in Europe, you're also breathing in a hidden killer, even when the sky is a brilliant blue.

We now know that the invisible gas nitrogen dioxide can seriously damage our health – and cities in Europe and the US have some of the world's highest NO₂ levels.

The good news is that these levels are declining. The bad news is that in many cities they are not declining fast enough to meet legal standards any time soon.

Worse still, even if air does meet those legal limits, it still won't be safe to breathe. Nearly half a million people in Europe die from air pollution every year – and most of those deaths are being caused by breathing air that is supposedly “safe”. It kills more people than obesity or alcohol – only smoking is more dangerous.

If we want to live longer, healthier lives, we need to go way beyond the current standards. That means changing our transport systems: ditching diesel cars for hydrogen or electric ones, and cycling or walking more.

Diesel vehicles are the biggest source of NO₂, and Europe's roads are now full of diesel cars thanks to low-carbon policies that encouraged people to buy them.

It used to be debated whether NO₂ was harmful itself, or merely appeared to be because high levels of it usually coincide with high levels of particulate pollutants. Now there is strong evidence that NO₂ on its own has a wide range of harmful effects.

It lowers birthweight, stunts lung growth in children and increases the risk of respiratory

infections and cardiovascular disease. Particulate pollutants like soot cause a wider range of problems, including lung cancer.

While air pollution doesn't kill directly, statisticians express its life-shortening effects in terms of deaths per year. A report out

“Air pollution kills more people than obesity or alcohol – only smoking is more dangerous”

earlier this year concluded that particulate pollution causes the equivalent of 30,000 deaths in the UK every year, while NO₂ kills 10,000. These figures suggest air pollution is second only to smoking in terms of the harm it does.

And this is just what we have good evidence for. Air pollution is also suspected to increase the risk of conditions including diabetes, dementia and autism. Earlier this

year, a study found millions of tiny iron particles in brain tissues, probably from exhaust fumes.

The bottom line is clear. “Reducing pollution levels in cities is likely to have massive health benefits,” says Adrian Barnett at the Queensland University of Technology in Australia.

According to European Union regulations that came into force in 2010, NO₂ should average no more than 40 micrograms per



Commuter health hazard

CHARLES PLATIAU / REUTERS

cubic metre over a year (the US standard is less strict: 100 µg/m³ over a year), and should not exceed an average 200 µg/m³ over an hour more than 18 times in a year. These limits are still breached in half of EU countries.

Take London: the city centre exceeds the 40 µg/m³ annual average limit, and in some parts the hourly maximum limit was breached in the very first week of January this year.

Off road solution

There is no doubt about the main cause of the problem: road traffic – mostly diesel vehicles – produces about half of the air pollution in our cities. In theory, cleaner exhaust systems should have reduced NO₂ pollution despite the rising numbers of diesel cars, but as the Volkswagen scandal made clear, newer vehicles are not as clean as they are supposed to be.

So in simple terms, lowering air pollution boils down to getting the most-polluting diesel vehicles off busy city roads. Some nations are taking this seriously: many German cities already have clean air zones, for instance. The UK government, however, has done so little that it is being taken to court for a second time by environmental campaign group ClientEarth over its failure to act – having already lost the first case.

The mayor of London, Sadiq Khan, this year announced plans to tackle air pollution in the city. But more needs to be done if London is to meet the legal limits within a decade, says Richard Howard from the Policy Exchange think tank in London.

For instance, one plan is for owners of diesel cars made before 2005 to pay a “toxicity charge” from 2017 if they enter central London. But this will make little difference: while diesel cars made between 2005 and 2014 do better in lab tests, they produce just as much NO₂ in real-world driving as older models, Howard says.

Some clean air campaigners want to see diesel vehicles phased out entirely. “In the longer term, we need to be looking beyond diesel,” says Alan Andrews of ClientEarth. “The days of diesel cars are numbered.”

But getting them off our roads is a huge challenge. While opinion polls suggest strong support for cutting air pollution, there could be a big backlash when millions of drivers realise they will be hit by an “ultra low emissions zone” planned for London in 2019. Paris has already seen protests against its air pollution efforts. “I’d be amazed if Sadiq manages to push the policy through,” says Howard.

For this reason, many campaigners are calling for a national scrappage scheme to help people cover the cost of replacing diesel cars with hybrid or electric ones. It will be money well spent, they argue, given the price of inaction on air pollution.

Indeed, a 2010 European Commission study estimated that dirty air costs the UK some £5 billion a year in terms of lost working days, admissions to hospitals and so on. When a monetary value is put on deaths, based on what people say they are prepared to pay to reduce their risk of dying early, the figure soars to up to £50 billion a year.

Cash-strapped governments aren’t keen on scrappage schemes, yet without central government support, big cities like London will struggle to meet

“If we are serious about improving health, meeting current legal limits should just be the start”

the legal limits for air pollution. And here’s the real shocker: even meeting these limits won’t solve the air pollution problem.

Remember those 30,000 deaths per year from particulate pollution? Almost all are due to exposure to levels below the legal limit. “The particulate matter limit is not currently protecting

HOW TO PROTECT YOURSELF FROM AIR POLLUTION

Properly combating air pollution will require government action (see main story), but here’s what you can do to avoid the worst of its effects

Avoid busy roads

Road traffic is the main source of outdoor air pollution. If you can’t avoid busy roads, try to travel outside the rush hour



Avoid candles and wood fires

Burning anything in your home produces harmful pollutants



Walk or cycle

Counter-intuitively, getting out of the car will reduce exposure, but it is still best to pick quieter routes



Open windows when cooking

Gas cookers produce lots of harmful nitrogen dioxide



Don’t smoke

In case it’s not obvious, smoking is by far the worst form of air pollution



Don’t buy a diesel car

If you’re replacing your ride, don’t buy diesel. Choose an electric, hybrid or petrol vehicle instead



Get some exercise

While exertion increases your exposure to air pollution as you breathe more, benefits outweigh the risks



Buy a houseplant

They look good and help mop up dangerous chemicals released by household products



health,” says Frank Kelly of King’s College London.

The EU limit for particulates smaller than 10 micrometres in diameter (PM₁₀s) is twice that recommended by the World Health Organization, says Kelly. All of central London exceeds this stricter limit, which some say still isn’t enough. “There’s no safe level of air pollution,” says Barnett.

So if we are serious about improving health, meeting the current legal limits should just be the start. The next stage is to get air pollution down to negligible levels, says Laurie Laybourn-Langton at the Institute for Public Policy Research in London. “It’s a much deeper and longer battle.”

The implications are enormous. Not all air pollution from road traffic comes from exhaust fumes. In cities, about half the particulates comes from brake pads and a tenth from tyres.

Another quarter comes from traffic stirring up dirt on roads.

So even switching to electric vehicles won’t solve the problem. One 2016 study (*Energies*, doi.org/br6t) estimated that electric cars still produce an eighth of the PM₁₀s that new diesels do and half as much as petrol cars do.

This leads to a conclusion that many won’t like: if we want to cut air pollution in big cities to low levels, we need to cut traffic. Looking on the bright side, tackling air pollution the right way could be a win-win situation. Switching to electric vehicles will slash CO₂ emissions, and encouraging more people to walk and cycle has health benefits.

“We are not in a situation where there are no alternative options to dirty cars,” says Laybourn-Langton. “There are more alternative options than ever before.” ■

A toothless idea

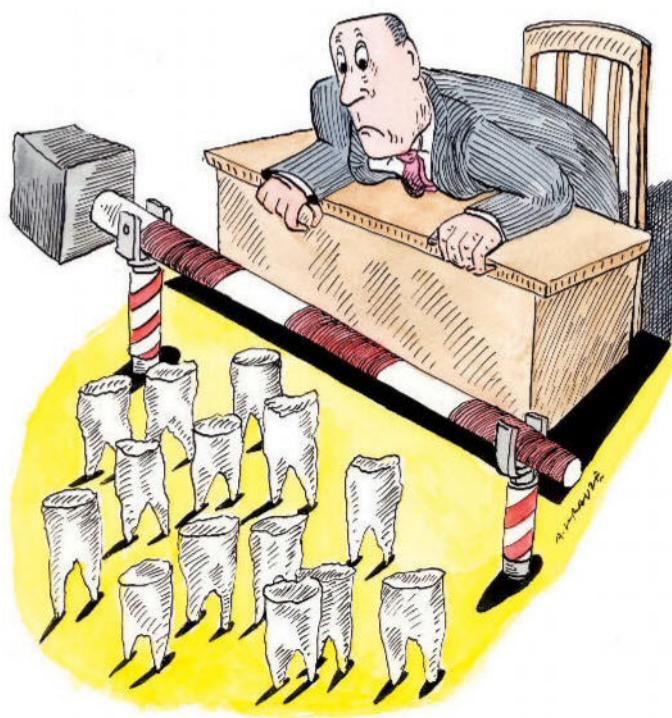
Dental checks won't verify whether or not people seeking asylum in the UK are actually children, says **Tim Cole**

IMAGES of asylum-seeking children arriving in the UK have sparked concern, with several Tory MPs questioning their age and proposing dental checks to make sure they are not adults.

The UK government recently agreed to take in some unaccompanied minors from a refugee camp in Calais, France. Such people often lack documents. It is the first of those arrivals, from nations such as Afghanistan, that have sparked the call for the tests.

But the idea of using dental X-rays, or similar methods such as wrist bone scans, is far from an ideal way of verifying age.

It relies on the concept of physical development, in this case that teeth and bones of growing children – as seen on an X-ray – change in appearance over time. These changes can be calibrated against a reference group of children to provide a



developmental age – the age at which an average child reaches each stage. At a certain point, the appearance reaches the final adult stage, after which the bone or tooth is mature and does not change. The key assumption of such tests is that if an individual's teeth or bones have reached the adult stage, then they are over 18.

But that is too simplistic and often gives the wrong answer, because developmental timing is variable. Take the growth spurt during puberty, or when girls start their periods; the age of onset can vary by up to five years.

Bones and teeth are even more variable, reaching the mature stage somewhere between the ages of about 15 and 23.

The dental approach focuses on wisdom teeth and can give the wrong answer in two ways. If the tooth is mature, then the person is assumed to be an adult even if

Unspeakable failings

US presidential debates had no climate change questions. It's a farce, says **Matthew Nisbet**

THIS is getting repetitive. The third and final US presidential debate ended without moderating journalist Chris Wallace asking a single question about climate change, and with only a fleeting reference to the issue by one of the candidates. In this, it resembled the first and second debates.

The final debate, held in Las Vegas, Nevada, came as disaster-level drought continues to plague the US West Coast and in the same week that scientists declared September the hottest on record. It was also within days of nearly 200 countries approving yet another historic agreement to limit greenhouse

gas emissions, this time tackling hydrofluorocarbons.

On the economy, Hillary Clinton said she wanted "new jobs in clean energy. Not only to fight climate change, which is a serious problem, but to create new opportunities and new businesses." That was it. A handful of seconds devoted to the biggest challenge facing the planet and the US's most far-reaching national security threat.

In all, across 360 minutes of

"That was it. A handful of seconds devoted to the biggest challenge facing the planet"

presidential and vice-presidential debate, climate change received just five-and-a-half minutes of discussion, all in passing.

To be sure, Donald Trump's outrageousness has sucked the air from most substantive discussion of policy issues. Yet Wallace and the journalists who moderated previous debates have questioned the candidates directly about Syria six times, terrorism four times and the national debt twice.

The failure is even more glaring when you consider that the moderators have asked more than 15 questions about the candidates' faith, appearance, tweets, behaviour, foundations, taxes,

they are a child. If the tooth is immature, they are assumed to be a child even if they are an adult.

In the first case, a child will be denied care by the local authority, which may harm their well-being. While in the second, an adult will be treated as a child, supported by the authority and housed with children. Neither is desirable.

The risk of getting a misleading result is high. Broadly, there is a 10 per cent chance of a child being assessed as an adult, and a 50 per cent chance of an adult being assessed as a child. The average error of 30 per cent means that about one in three assessments will be wrong. It is only roughly between the ages of 25 and 30 that this test becomes accurate. Wrist bone scans have also been used for age assessment, but they are even less useful.

Such figures are no doubt why the Home Office has dismissed the calls for tooth tests.

Such checks seem appealing because they are scientific and objective. That's probably why some politicians reach for them on tricky issues. But to claim they can accurately tell a child from an adult is wrong. ■

Tim Cole is a professor of medical statistics at UCL Great Ormond Street Institute of Child Health, London

paid speeches, public comments or alleged sexual behaviour.

The moderators might point to polls showing that climate change ranks at the bottom of perceived policy priorities for the public. But we need journalists to step up on climate change, to fulfil their professional duty to focus on and cover issues no matter how complex or divisive, and to alert the public to what truly matters.

History will show that, in this election, the debate moderators failed us. ■

Matthew Nisbet is professor of communication at Northeastern University in Boston

INSIGHT Face recognition



JOHN MOORE/GETTY

Say cheese

Face recognition in the US will net innocents

Hal Hodson

LIVE in the US? There's a 50:50 chance that you're in a police face recognition database, according to a report from the Center on Privacy & Technology at Georgetown Law in Washington DC. The findings suggest that about a quarter of US police departments have access to face recognition technology.

That police are using this tech is not a problem in itself. In a world where we're constantly on camera, they would be daft not to. But face recognition can be used far more broadly than fingerprint recognition, which means it carries a higher risk of tagging innocent people.

Fingerprints are tricky to work with. Criminals' prints are only gathered at police stations, and dusting for prints is only done at relevant crime scenes. This narrows the number of people in the sights of any one investigation.

It's much easier to build huge databases of identified photographs. The majority of the 117 million faces in the US police datasets come from state driving licences and ID cards. And when trying to solve a crime, gathering faces is as easy as pointing a camera.

People attending protests, visiting church or just walking by can all have their faces "dusted" without knowing.

That means most of the faces in the database are innocent people, not hardened crooks, increasing the chance of police mistakes.

And face recognition software is far from perfect. Under ideal conditions, which are rarely achieved in reality, face recognition is less accurate than fingerprint recognition.

Facebook's face recognition software has made headlines for "closely approaching human-level performance", but systems dealing

"Most faces in the database are innocent, not hardened crooks, increasing the chance of police mistakes"

with grainy CCTV images are nowhere near this good. A big database of innocent people could actually make it harder to fight crime, because the software may start turning up more false matches than humans can check.

There are next to no regulations on how the police use this technology, or how much weight they give to its

results. Without guidance, officers may overvalue the software's output, and unconsciously favour evidence that matches its results.

Face recognition systems are also likely to be biased against black people. Since black people are arrested more often than white people, black faces are over-represented in the mugshot databases. This means faulty face recognition is more likely to link innocent black people to a crime than innocent white people.

At the same time, research from 2012 has shown that commercial face recognition software is less accurate at analysing the faces of black people, women and children, compared with white men. So not only is the software likely to point the finger at a larger number of black people, it also points less accurately at them.

Not even the FBI knows what it's doing. In May, a US Government Accountability Office (GAO) report on the FBI's face recognition programme said that the agency had not tested to see how often errors occurred. Doing so would mean the FBI could be more sure that its system "provides leads that help enhance, rather than hinder, criminal investigations", said the GAO.

Like all forensic techniques, face recognition has the power to catch criminals police might otherwise miss. But to do so, its results must be transparent and reliable – otherwise you might as well just pick someone out of the crowd. ■

BEAUTIFUL SCIENCE

When it comes to innovative research, creative thinking and a strong commitment to sustainability, few companies can match one of the giants of the cosmetics industry

As food fads go, few have equalled the explosive popularity of quinoa. The seeds of this relative of spinach are rich in carbohydrates, low in fat and gluten free. Since 2000, global sales have almost quadrupled.

For the producers, most of whom are in the Andean region of South America, this boom also generated headaches. The edible part of quinoa is covered in a bitter husk that must be removed. Husks make up 10 per cent of the grain's weight, so create a mountain of waste.

Enter L'Oréal, the French cosmetics company based in Clichy, north-western Paris. Quinoa caught the company's eye a few years ago because the husks contain a cocktail of chemicals ideal for exfoliating human skin.

After extensive testing, the company decided to include quinoa husk extract in a new skin softener. That kick-started a vibrant partnership with 250 farmers in southern Bolivia, improving their lives not least by giving them a second income, for their troublesome waste.

The tale of quinoa husk is an example of L'Oréal's programme "Sharing Beauty with All". It's a business philosophy that places sustainability at the heart of everything the company does. It extends to consumers, suppliers and distributors and has the goal of sharing the benefits

of success. And it's rooted in evidence-based science.

The beauty industry is by definition about appearance. But the glamour you see in adverts for L'Oréal's products sits at the pinnacle of a vast scientific endeavour. It's a business that needs everyone from botanists to chemists, production engineers to environmental scientists and programmers to agricultural scientists to be at their creative best.

"It is important for us to be able to attract the best scientists," says Laurent Gilbert, sustainable innovation director at L'Oréal. "That means the best in their field of expertise, the most curious, open minded, and able to work in cross disciplinary teams."

GUIDING PRINCIPLES

One of the driving forces of the work they do is green chemistry, the idea of reducing consumption of non-renewable resources and preventing pollution. L'Oréal has been a pioneer in the field. "We implemented the principles of green chemistry in 2005 and were the first to do it," says Michel Philippe, a senior research associate and one of L'Oréal's top chemists.

The company has three core principles that guide its work: raw materials should be plant-based and renewable, manufacturing

processes should be environmentally friendly, and all the company's activities should protect health and the environment.

To implement these on an industrial scale, L'Oréal uses several indexes. Its "origin index", for example, rates materials on a scale of 1 to 5. Plant-based ingredients that have not been processed and are obtained using sustainable agriculture score highest. Materials that are chemically synthesised from fossil fuels score 2 and those obtained from animals score 1.

L'Oréal grades its manufacturing processes on its "denaturation index". Solvent-free processes, such as grinding, pressing and drying, that do not change the chemical nature of a material, attract a 5. But processes that need petrochemicals or otherwise harm the environment attract a score of 2 or 1.

Then there is waste, which is captured by the environmental or "e-factor" - the ratio of waste generated to product produced. So a process that creates 50 times as much waste as product has an e-factor of 50.

These metrics let L'Oréal measure its performance and set targets, such as increasing the amount of renewable ingredients it uses. In 2014, the company rated 46 per cent of its ingredients as renewable. "In 2015 this rose to 52

Quinoa husks (right) used to be a big problem. But not any more



L'Oréal scientists in France (bottom) found a use for quinoa husks, grown in Bolivia (top)



JAMES MORGAN GETTY IMAGES

per cent,” says Gilbert. The company aims to push that figure higher.

One of L'Oréal's green-chemistry creations is Pro-Xylane, a compound that reverses changes seen in ageing skin. It mimics a naturally-occurring sugar called xylose which stimulates the formation of glycosaminoglycans, or GAGs.

These molecules form part of the skin's support structure and are strong attractors of water. As skin ages, GAG levels drop and skin becomes drier, less well toned and more prone to wrinkling.

Studies found that Pro-Xylane increases the production of GAGs and reduces wrinkles and sagging.

It is now an important ingredient in products such as Skin Genesis.

It is also a green product. L'Oréal makes Pro-Xylane by modifying xylose from beech trees in a two-step process, giving it an origin index of 4, a denaturation index of 3 and an e-factor of 4.9. By contrast, the pharmaceutical industry operates with e-factors ranging from 25 to 100.

Another compound with anti-wrinkle effects was the result of some inspired lateral thinking. Botanists have long known that plants under duress release jasmonic acid to help heal wounds and repair tissue. L'Oréal researchers wondered if this or a related substance might help

“Always we have the same idea: there really is a link between sustainable practice and social benefit for the community”

repair human skin as well.

They screened a range of derivatives of the acid and found one that stimulates skin cells to express proteins that promote renewal and thickening of the skin. Trials of the compound, now called LR2412, found it helped to smooth out wrinkles and it is now in products such as L'Oréal's Advanced Skin Corrector. What's more, it can be made relatively easily with minimal waste, so has an e-factor of just 1.5.

These products may be triumphs of creativity and green chemistry, but larger challenges lie ahead. For example, at present the molecules based on rings of carbon atoms used in hair dyes and sun filters can be derived efficiently only from petrochemicals. Finding an environmentally friendly way to make these is an important goal, says Philippe.

The company's ambitions don't end there. “By 2020, 100 per cent of our products will have some environmental or social benefit,” says Philippe. Quinoa husk extract is a case in point. When L'Oréal first approached them, the Bolivian farmers had low crop yields and were destroying their soils. “We realised that we were facing some difficulties,” says Gilbert.

The company offered the farmers training in sustainable agriculture and encouraged them to use native plants to combat soil erosion. The result is a win-win-win situation: L'Oréal has a new sustainable source for its cosmetics, consumers have a greener product and the farming communities are better off financially, environmentally and have a sustainable future.

“We are doing the same in India, in Burkina Faso and elsewhere,” says Gilbert. “Always we have the same idea: there really is a link between sustainable practice and environmental and social benefits for the community.” For L'Oréal, that is the meaning of “sharing beauty with all”.

A watchful eye

Cameras can monitor vital signs from a distance. **Hal Hodson** explores the tech being tested on hospital wards

BEEPING monitors. Stick-on electrodes. The finger clip that takes your pulse. Modern medicine comes with a cacophony of sensors. Oxehealth, a company spun out from the University of Oxford, is aiming to replace them all with just one – a camera.

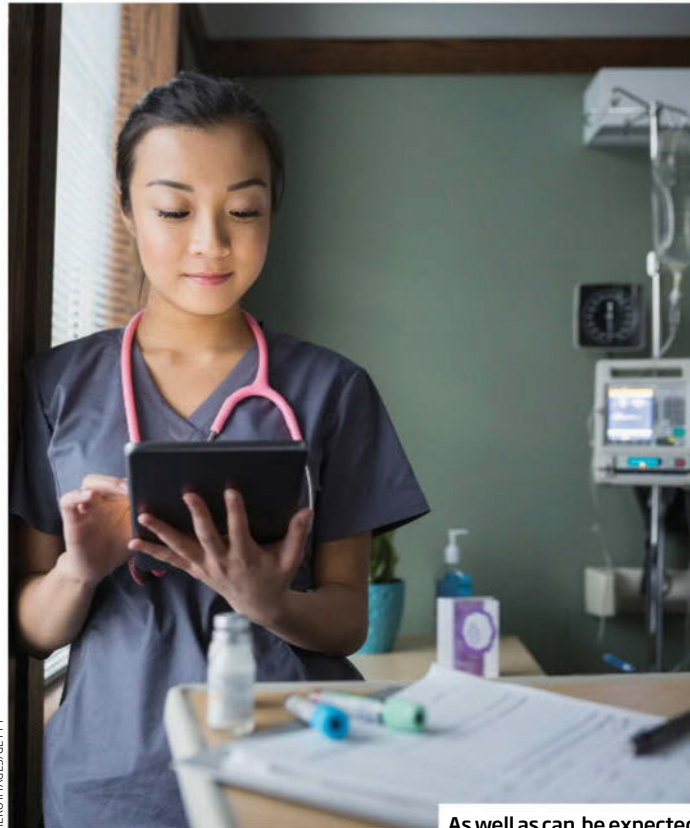
Oxehealth's software uses camera data to measure heart rate, respiration and blood oxygenation from a distance. The company is now trying out the technology in the real world, in hospitals, psychiatric wards and police stations.

One place the tech is being tested is at the John Radcliffe, Oxford's main teaching hospital. Patients who will need a spell in intensive care after their surgery are being asked to participate in the trial: Oxehealth's cameras will monitor their vital signs in parallel with conventional sensors.

"Normal monitoring involves sticking things on patients," says Peter Watkinson, an intensive care doctor for Oxford University Hospital Trust. "It makes it less easy for them to get out of bed, have a shower or go to the loo. Every time you roll over in bed you pull the thing off."

The Oxehealth software watches for the tiny changes in video frames as a patient's chest rises and falls when they breathe, for example. It also tracks subtle changes in the pinkness of their skin, using that to infer their pulse.

Watkinson thinks camera monitoring will make it possible to catch patients whose condition is deteriorating before their symptoms are obvious. At the moment, clinicians have to decide which patients they need to monitor – usually those who are recovering from a procedure or



HERO IMAGES/GETTY

As well as can be expected

are already very ill. But the cameras would be able to keep tabs on everyone in their vicinity.

"It would be much more reliable at picking up patients at risk of deterioration throughout

"With camera monitoring you can catch patients who are deteriorating before symptoms are obvious"

the hospital," says Watkinson.

Oxehealth's Oliver Gibson says the company has also been running studies with London's Metropolitan Police Service and Broadmoor high-security psychiatric hospital. Here the firm

is "trying to solve the problem of making sure someone is safe when they're in a secure room".

In April, Broadmoor installed cameras in one of its rooms. Staff would sit there during the day, while patients would sleep in it at night. Both were wired up with sensors to validate the readings the cameras took.

Broadmoor's patients need regular monitoring, says the hospital's director Robert Bates – especially at night. "We usually check on patients every 15 minutes," he says. It can be hard to tell whether someone is breathing just by looking through their door, so staff have to approach

patients to make sure they're OK. "It's upsetting for the patients because they're being regularly disturbed," says Bates.

The camera system could offer a less intrusive means of keeping tabs on residents. "It will also help us monitor our patients' physical health after administration of medication," says Bates. "Anti-psychotics can have an impact on patients' physical health."

Gibson says the Broadmoor study confirmed the cameras' accuracy. "We were getting a breathing rate accuracy where 94 per cent of measures were within two breaths per minute of a contact device," he says. "And 94 per cent of heart rate measures were within three beats per minute."

Oxehealth is not alone in hoping to free patients from their wires. Steffen Leonhardt at RWTH Aachen University in Germany is setting up a wireless monitoring ward in the university hospital. Six beds in the geriatrics department will have cameras monitoring their occupants' vitals.

Leonhardt says the system could one day be installed in elderly people's homes. "The reach will be large as we have an ageing population," he says.

The biggest advantage of camera monitoring may come after patients are discharged. Wiring people up to keep track of their health is impractical once they've left hospital, but camera-based systems could work.

"Perhaps people could go home earlier from hospital and we could monitor them remotely," says Watkinson. If chronically ill people could be monitored from home, he says, they could avoid coming into hospital at all. ■

Mini helper robots will scurry all over your clothing

OUTFIT missing that final touch? Try Rovables: pocket-sized robots that live on your clothes.

The bots, developed by a team at the Massachusetts Institute of Technology and Stanford University, look like miniature cars with a custom-designed circuit board for a roof. With the help of three magnetic wheels that allow them to cling, they roam freely up and down fabric for 45 minutes at a stretch, stopping in place to pose as a brooch or a bracelet.

But the robots aren't just there to make you look cool. At this week's User Interface Software and Technology Symposium in Tokyo, the team described how Rovables could also have practical uses as sensors, digital displays, or for tactile feedback.

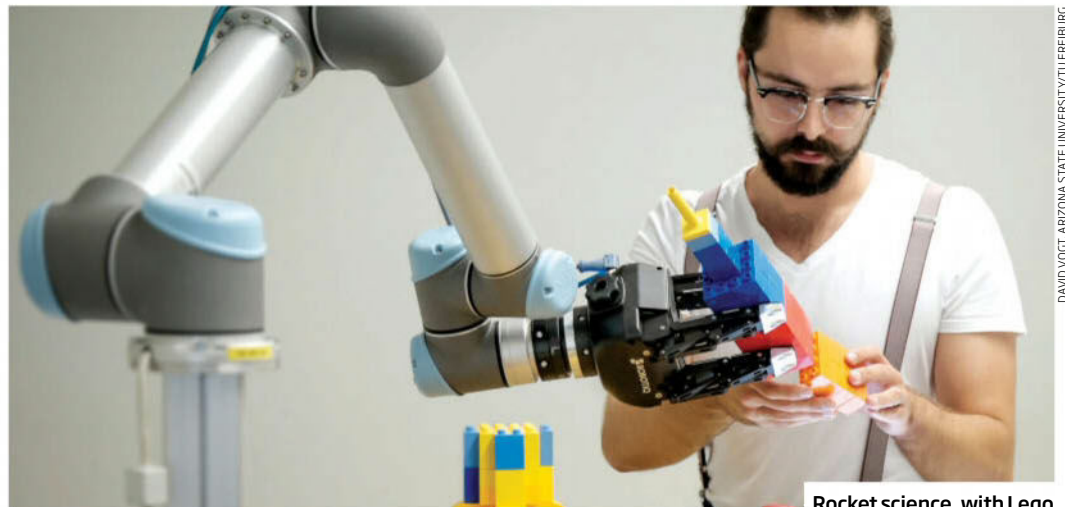
In one demonstration, two Rovables snap together on the chest to form a makeshift name tag. The bots also care for themselves by zipping over to a wearable charger when their batteries run low.

In the future, the researchers imagine that Rovables might be fingernail-sized and go scurrying around your clothes on a programmed routine: onto your limbs to track your movements at the gym, up to your neck to let you take an incoming call, then over to your back to flash lights while you cycle home from work in the dark. **Aviva Rutkin** ■



Sitting pretty

MIT MEDIA LAB, STANFORD UNIVERSITY



Rocket science, with Lego

DAVID VOGT, ARIZONA STATE UNIVERSITY/TU FREIBURG

Robots: just look at me and copy what I do

DAVID VOGT'S son loves Lego. As they played together one day, the robotics professor had an idea: could he teach a robot to put the blocks together?

"We thought it would be funny to make a robot that could do the same thing I am doing with my son," says Vogt, who is at the Freiburg University of Mining and Technology in Germany.

So Vogt and his colleagues brought an industrial robot arm to the lab. Like a child playing for the first time, the robot – equipped with a Kinect depth camera – observed two experienced humans wearing motion tracking tags as they built a Lego rocket. After just one session, the robot was able to partner with a human to build the rocket. It could also cope with some blocks not being exactly where it expected to find them.

The project, to be presented next month at the International Conference on Humanoid Robots in Cancun, Mexico, is one of several recent examples of teaching robots through human demonstration.

Humans learn how to do lots of things by watching someone else, but programming a new skill into

robots is difficult, says Aude Billard at the Swiss Federal Institute of Technology in Lausanne. We know intuitively how to do certain tasks, but struggle to express that knowledge as programming.

Instead, engineers have found ways to show robots what to do, rather than tell them. Some remotely control the robot through its first few tries, getting

"A good teacher will understand that the robot has different ways of perceiving the world"

a sense of its experience using the buzz of haptic feedback. And last year, a robot at the University of Maryland started learning to cook by watching YouTube videos of people in the kitchen.

In work published earlier this month, researchers at Google took a hands-on approach, teaching a robot how to open a door by physically guiding it through each step. Later the robot tried on its own, starting with a similar door. It was then able to apply what it had learned to open doors even when their orientation was

different to what it had encountered before.

"We have a lot of intuition about how various manipulation skills can be performed, and it only seems natural that transferring this intuition to robots can help them learn these skills a lot faster," the Google researchers wrote.

Another trick is to make sure the data is translated in a way that makes sense for that particular robot. Most robots don't have structures or sensors that mirror the human anatomy, for example. "Part of being a good teacher is understanding that the device that you're teaching has different ways of acting in the world and different ways of perceiving it," says Billard.

Vogt's team thinks that learning through human demonstrations will make robots better able to assist humans with skilled factory work. This could mean having the right tool ready when a worker needs it or stepping in to perform some tasks on its own. That could relieve some of the physical stress on workers, says team member Heni Ben Amor at Arizona State University in Tempe.

"Ideally, humans and robots together should be able to do something that, individually or separately, they wouldn't have been able to do alone," he says.

Aviva Rutkin ■

Play it for real

Grand Theft Auto can train self-driving cars, says **Timothy Revell**

GETTING computers to recognise other cars is surprisingly difficult. Earlier this year, the first fatal autonomous car crash happened when a Tesla Model S failed to distinguish a white truck against a brightly lit sky.

Now a study has shown that self-driving cars can be taught the rules of the road by studying virtual traffic on video games such as *Grand Theft Auto V* (GTA V).

Although firms like Google and Uber are teaching their software by physically driving millions of miles in the real world, they also train their algorithms using pre-recorded footage of traffic. But there's a catch: computers need hundreds of thousands of laboriously labelled images, showing where vehicles begin and end, to make them expert vehicle

recognisers. That takes people a lot of time and effort.

"One evening, after a long day of hand-labelling images, I was playing *Grand Theft Auto V*," says Matthew Johnson-Roberson at the University of Michigan in Ann Arbor. "I thought, 'this is just so realistic that it would be a perfect simulation of the real world'."

Picking out cars in a video game is a similar task to doing it in reality, with the advantage that everything comes pre-labelled because it has been generated by the game's software. The team trained an algorithm solely using GTA V and tested it against the same algorithm trained on real-world images. The GTA-trained one performed just as well at spotting cars in a pre-labelled data set (arxiv.org/abs/1610.01983).

The video-game version needed around 100 times more training images to reach the same standard – but given that 500,000 images can be generated from the game overnight, that is not a problem.

This isn't the first time a research group has used video games to train AI, says German Ros at the Autonomous University of Barcelona in Spain. "It's part of a bigger movement

"I thought, 'this is just so realistic that it would be a perfect simulation of the real world' "

of using simulations to train artificial intelligence, which is beginning to take off."

Finding the right training data is difficult. "We see AI being trained on images from similar locations, at similar times of day, under similar weather conditions, and then tested under similar conditions," says Ros. This means that it's hard to tell whether the computers can genuinely recognise cars, or whether they have just memorised that particular data set.

Using video games can help because they often show a variety of vehicles and conditions – but the problem is still there. "There's nothing in GTA V that looks like a city in Japan, for example," says Ros.

We have to show that driverless cars are safer than human-driven ones. In the real world, there is a car fatality for every 100 million miles driven. Racking up that kind of distance with a prototype is not easy. "The first step could be to make sure every system has been tested using video-game-style simulations before it hits the road," says Johnson-Roberson. ■



Driver 1: ready

ROCKSTAR GAMES



Post-it 2.0

Lighten up your desk life. Microsoft Research has developed a digital display powered by ambient light. The prototype is like a miniature e-reader with photovoltaic cells able to harvest energy from office lighting. The team suggests the tech could be used as a form of Post-it note that constantly updates itself with information such as the latest weather forecast or bus times.

61.23

The total value in bitcoin so far staked on Donald Trump winning the US election by users of bitcoin betting site BitBet. That's equivalent to \$38,500. However, 78.90 bitcoin says he won't.

Full autopilot

Just sit back, relax and enjoy the ride. Tesla says all the cars it makes from now on will have the hardware needed to drive fully autonomously, including cameras, radar and a new computer with 40 times the power of its predecessor. Elon Musk, Tesla's co-founder and CEO, says that one day you'll be able to "summon" your car by tapping a command on your phone – "even if you are on the other side of the country".

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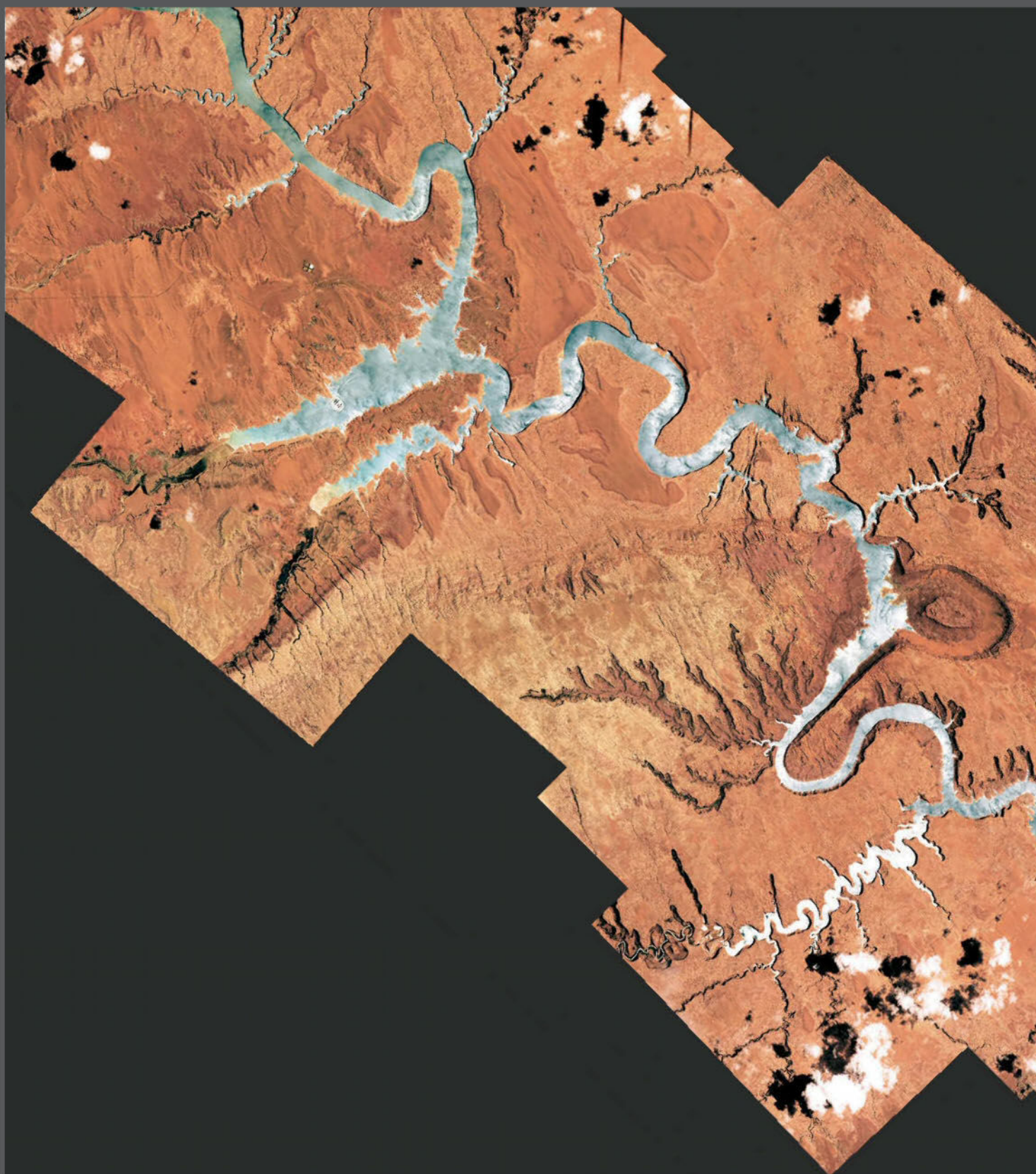
Daniel Becerra (Buffalo Grid), Thorsten Klaus (AlphaEOS),
Sally Adee (New Scientist) plus more speakers to be announced

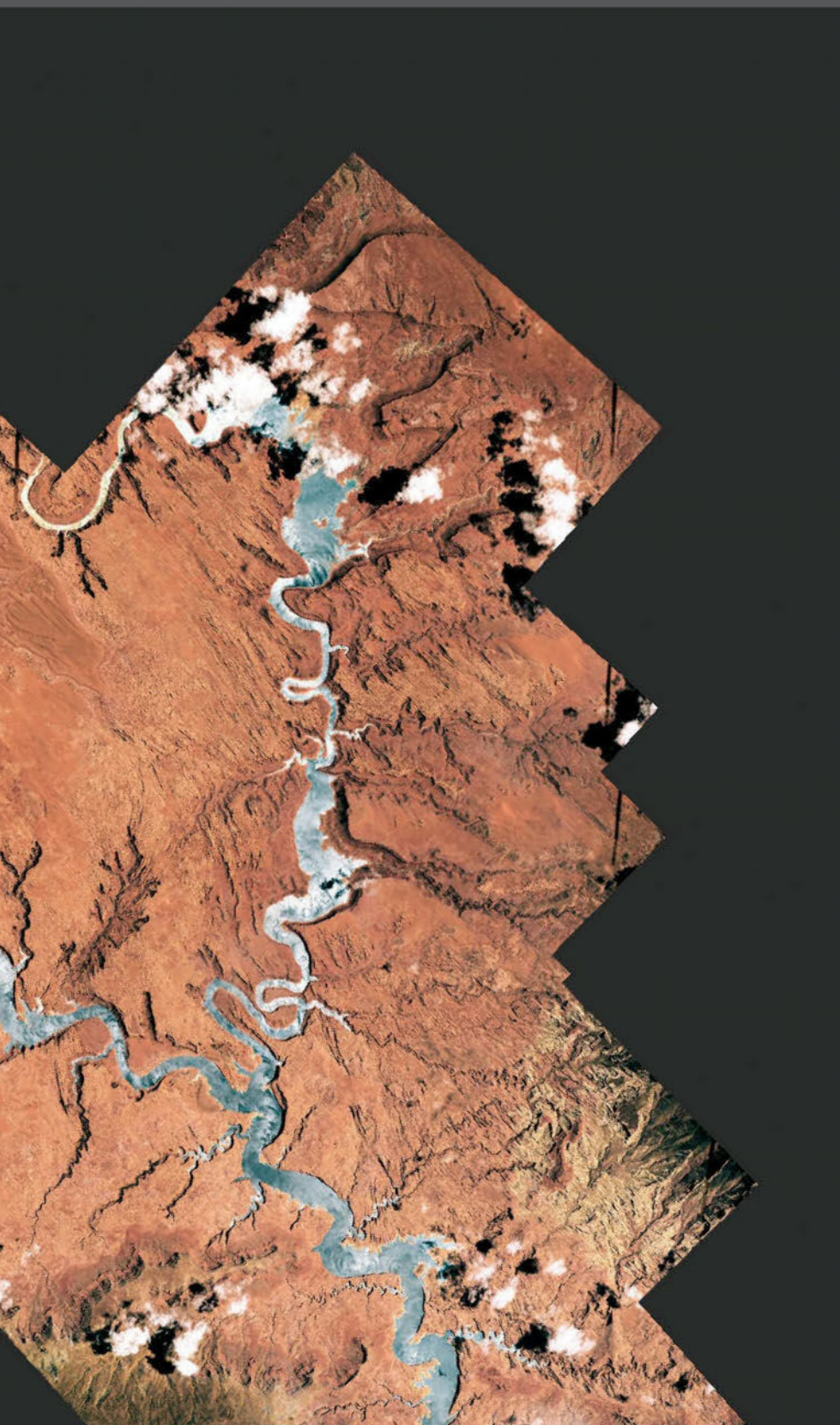


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Eye me a river

IF YOU can't make it in person to this spectacular stretch of the Colorado river, at least admire this snap from space.

An astronaut aboard the International Space Station took several shots earlier this year, and they were stitched together into this impressive patchwork of the Glen Canyon, approximately 500 kilometres north-east of the Grand Canyon.

The water gets its eerie hue from sunglint, an optical phenomenon that occurs when sunlight reflects directly from the water's surface into the camera lens.

The most distinctive object is the Rincon, the circular brown blob towards the centre of the mosaic (see picture below). An entrenched and abandoned meander, the Rincon was lost from the river several thousand years ago when the Colorado took a shortcut, lopping 10 kilometres off its course.

The finger-like brown feature to the left of the Rincon is Long Canyon, one of the largest of the valley's many canyons. To the far left of the image are two lakes, the larger being Bullfrog Bay and the smaller Hall's Creek Bay, two popular holiday resorts. Andy Coghlan



Photographer

NASA/JSC

Spooked?

What is it about almost-humans that gives us the creeps, wonders Laura Spinney

ON THE face of it, *The Polar Express* was a sure-fire winner: starring Tom Hanks, it told the charming story of a boy's magical train journey to the North Pole. But when the movie came out in 2004, there was a problem: the ultra-realistic animation gave some viewers the creeps. Five years later, when James Cameron chose the same technology for *Avatar*, his graphics people reportedly thought the decision might bankrupt the production company. But Cameron's blue humanoids went down a storm. For a while, *Avatar* was the highest-grossing film of all time.

You might have heard of the uncanny valley: the notion that the more human-like a non-human character becomes, the more we like it – until suddenly, we don't. At some point where it is almost, but not quite, human we become unsettled, even revolted. The uncanny valley has been used to explain our adverse reactions to all sorts of almost-humans from zombies, androids and corpses to the creepy clowns recently terrorising North America. The characters in *The Polar Express* strayed into the valley. Cameron's blue Na'vi did not. Why?

The Japanese roboticist Masahiro Mori first described the uncanny valley in 1970. It has since become a highly influential idea that has shaped not only films and video games, but also robots, dolls and prosthetic limbs. But it has only recently been tested scientifically. The result? Researchers are divided on almost every aspect of it, from why we experience it to

whether it actually exists. The uncanny valley, it seems, is weirder and more controversial than Mori could have predicted.

Mori's original paper was a warning to roboticists not to stray too close to human likeness, or risk repulsing the very people they wanted their robots to serve (see "The unbearable likeness of beings", page 31). But his thought experiment was based on intuition rather than empirical research, and evidence has been equivocal. This has led some to suggest that Mori was wrong. "The uncanny valley doesn't exist," says David

"Robots that look too human risk repulsing the people they are meant to serve"

Hanson at Hanson Robotics in Hong Kong. He agrees that human-like figures can elicit an uncanny or eerie sensation, but sees no evidence for a "valley" that opens up at a certain level of human resemblance.

Others believe that the valley does exist, but not as generally interpreted. "It's not meant to be literally true," says Karl MacDorman, who studies human-computer interaction at Indiana University in Indianapolis. "It's about the risk of provoking certain reactions." Understood correctly, he says, the uncanny valley can aid designers and even provide a tool for understanding dealings between humans, by comparing them with

human-android interactions.

Part of the problem, MacDorman says, is that Mori's meaning was lost in translation. Writing in Japanese, Mori coined the word *shinwakan* to describe our emotional response to a human-like creature. Over the years, *shinwakan* has been translated variously as affinity, familiarity, rapport, comfort level and likeability. These all have slightly different meanings, and crucially, some can have negative or positive values – likeability, for example – whereas others, such as familiarity, can't dip below zero. This might explain, among other results, why neuropsychologist Marcus Cheetham of the University of Zurich, Switzerland, and his team failed to find the uncanny valley in 2014 when they measured people's responses in terms of familiarity.

And there's a second reason why the phenomenon might have proved elusive: lab tests have often used computer-generated morphs that gradually turn a robot into a human. Volunteers are aware that these "hu-bots" cannot exist in the real world, and this may affect how they respond to them. Earlier this year, Maya Mathur, a cognitive scientist at Stanford University in California, and her colleague David Reichling of the University of California, San Francisco, tried to solve this problem by showing people images of 80 actual robots. Their findings support the uncanny valley and, says Mathur, give a crude indication of its location and extent (see "Locating the uncanny valley", page 30). ➤



LUISA WHITTON

Among those who believe that the valley exists, there are two broad schools of thought as to its cause. Both tap into our brain's evolved ability to detect a threat, and hence to survive in a dangerous environment such as the African savannah. The first puts it down to a phenomenon called category uncertainty. When we are unsure how to categorise a stimulus – is it lion or antelope, human or machine – that ambiguity gives rise to fear, which in turn triggers the fight-or-flight response. The second school invokes something called perceptual mismatch, which occurs when an entity has seemingly incongruous features. The mouth and nose may be human-like, for example, but the eyes appear dead.

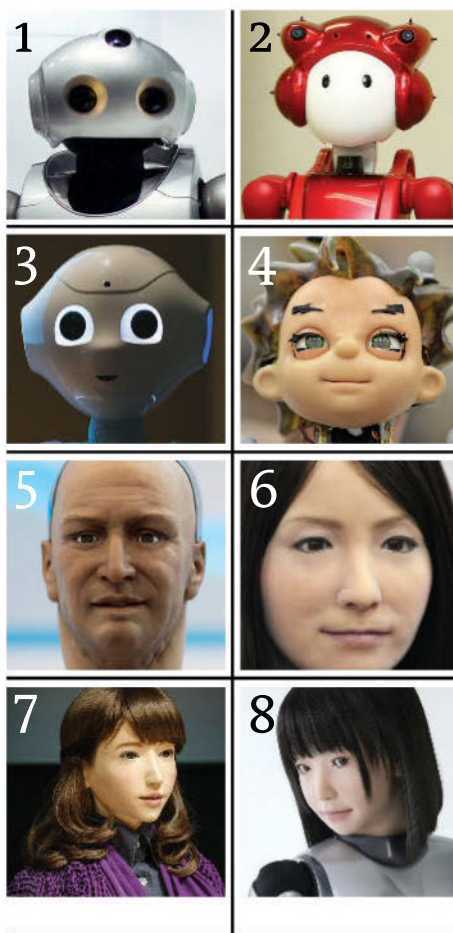
Whereas category uncertainty is conscious, perceptual mismatch is unconscious or preconscious. Your brain detects a conflict and infers a threat, but cannot consciously identify its source – perhaps something corpse-like about the creature taps into a hardwired desire

“Uncanniness taps into our brain’s evolved ability to detect a threat”

to protect ourselves from a potential source of infection, for instance. “Instead of producing fear, it produces anxiety – a kind of free-floating anxiety that can’t attach itself to any particular cause,” says MacDorman, who came up with the perceptual mismatch model. It’s an adaptive emotional response that enables us to maintain vigilance in the face of uncertainty.

The two explanations have very different implications. If category uncertainty is correct, to avoid eeriness roboticists and others should try not to make their creations too human-like, as Mori advised. In other words, they need to steer clear of the human-robot boundary. But if perceptual mismatch is the cause of uncanniness, avoiding it is more about maintaining consistency within the entity. Say you can give an avatar a highly realistic skin texture, for example, but truly lifelike eye movements are beyond your technical ability. To prevent your creation stumbling into the valley, you would deliberately use more artificial-looking skin so that the overall effect is a consistent level of realism.

Which idea is correct? Last year, a team of cognitive and computer scientists at Aalto University in Espoo, Finland, led by Jari Kätsyri, reviewed previous studies to see how well each hypothesis was supported. Starting with a sample of 125 peer-reviewed papers,



LOCATING THE UNCANNY VALLEY

Humanoid images generally become more likeable as they become more humanlike (from top left). But according to research by Maya Mathur at Stanford University, somewhere around image 4 a sense of unease sets in for most of us – before disappearing again around image 6

they removed those that didn’t meet their standards – not having enough volunteers, for example, or including morphed images of hu-bots that could not possibly exist in real life. They ended up with just 17 studies.

Overall, these did not support Mori’s original concept, tending instead to show a simple positive correlation between likeability and human likeness. However, they did show that the uncanny valley could arise under certain conditions – notably, those of

perceptual mismatch – and that incongruous eyes were particularly responsible for conjuring up eeriness. The Finnish group drew one more conclusion: corpses and zombies, which occupy the deepest part of the valley in Mori’s graph, should be excluded from the debate. “They are a distraction, because they elicit uneasiness for reasons besides being human-like,” says Kätsyri.

Soon after that review appeared, MacDorman and Debaleena Chattopadhyay, now at the University of Illinois, Chicago, published a study that pitted the category uncertainty and perceptual mismatch models against each other. They took a human face and gradually transformed it into a computer-animated version of itself. When they showed this to 500 volunteers, they found that people had no trouble categorising the fully computer-animated face as an animation, but they also found it the most eerie. In other words, although category uncertainty was not at play, there was still uncanniness. And the feeling of uncanniness could be enhanced if they made certain features within the morphing face – especially the eyes and mouth – appear more animated than the rest. MacDorman and Chattopadhyay concluded that perceptual mismatch was the most likely explanation for the uncanny valley.

The perceptual mismatch theory is much better investigated than category uncertainty, however, and some researchers believe the latter remains a contender. Psychologist Tyler Burleigh at the University of Guelph, Canada, thinks MacDorman and Chattopadhyay found no category effect because they did not test actual category boundaries – whether real or animated, the faces were still human. In 2013, Burleigh’s team showed people two series of images, one depicting the transformation from a human to a goat, the other from a human to an android-like creature with grey, inhuman skin. In other words, they toyed with the basic categories of human, animal and machine. “That’s where we find the effect – specifically where we manipulate the category membership,” says Burleigh.

So, it looks as if the jury is still out. And the questions don’t end there. Back in 1970, Mori wrote that the way a creature moves is critical to invoking eeriness, but very few researchers have explored the effect of movement. One who has is cognitive scientist Ayse Saygin at the University of California, San Diego. She has used functional MRI to show that people’s brains register an error when they see a human-like creature moving robotically, but not when they see either a human moving



While some may want to harness such reactions, in other domains the uncanny valley is to be avoided at all costs: cosmetic surgery, for one. At the University of Louisville in Kentucky, plastic surgeon Joshua Choo is designing a study to explore when surgically

“In cosmetic surgery, the uncanny valley must be avoided at all costs”

altered faces trigger perceptual mismatch. “A patient will come to you and say, I want this person’s nose,” he says. “And you can have a successful result, if you look at the nose and crop out everything else, but when you take it in the context of the whole face, it looks odd.” Choo hopes his findings will help those in his profession avoid creating that “operated-on” look.

Others who work on the margins of the uncanny valley and would rather not stray inside have a different problem. Kätysyri, now at Maastricht University in the Netherlands, thinks that if the perceptual mismatch theory is correct, the uncanny valley will be increasingly difficult to avoid as robots and avatars become more realistic, because some elements of their appearance just won’t be as polished as others. That doesn’t mean designers should shy away from what he calls the “grand challenge” of building human-like beings. But for many practical applications, there may be wisdom in Mori’s advice to go for only moderately human-like androids.

Nevertheless, some androids are already so realistic that they seem to have escaped the valley and regained the sunny uplands of likeability again – at least in static images. These include several built by Hanson’s company. Being sceptical of the uncanny valley phenomenon, Hanson finds it easy to ignore it when designing robots, but he thinks that the very idea of it might be limiting creativity in other designers by discouraging them from exploring how to get around or even harness uncanniness.

Perhaps fittingly, MacDorman takes the contrary view: that only by understanding the uncanny valley can you “design your way out of it”. Either way, we still have more to learn if we want to harness the power of uncanniness – whether it be to create blockbusting movies with avatars or to keep spooky almost-humans at bay. ■

Laura Spinney is a writer based in Paris, France

naturally, or a robot moving mechanically. Kätysyri even suggests that there may be more than one uncanny valley, occupying different dimensions of perceptual experience. It’s possible, for example, that some entities do not evoke uncanniness until they move.

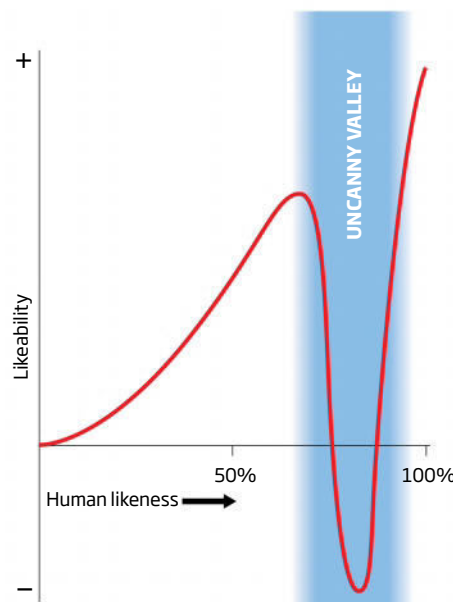
If the cause of uneasiness is still up for grabs, our reactions to it are even less well understood. Oddly, we don’t necessarily run from the uncanny valley. Sometimes we are drawn to it, showing a morbid fascination for the eerie and the almost-human. The entire horror film industry depends on this reaction, and video games are now capitalising on it too. Burleigh cites the popular *Silent Hill* series as an example: “There’s a really good case of using human-like monstrosities to enhance the horror experience,” he says. However, to exploit this effect, it would be useful to understand the circumstances in which uncanniness elicits morbid fascination or another paradoxical response, amusement.

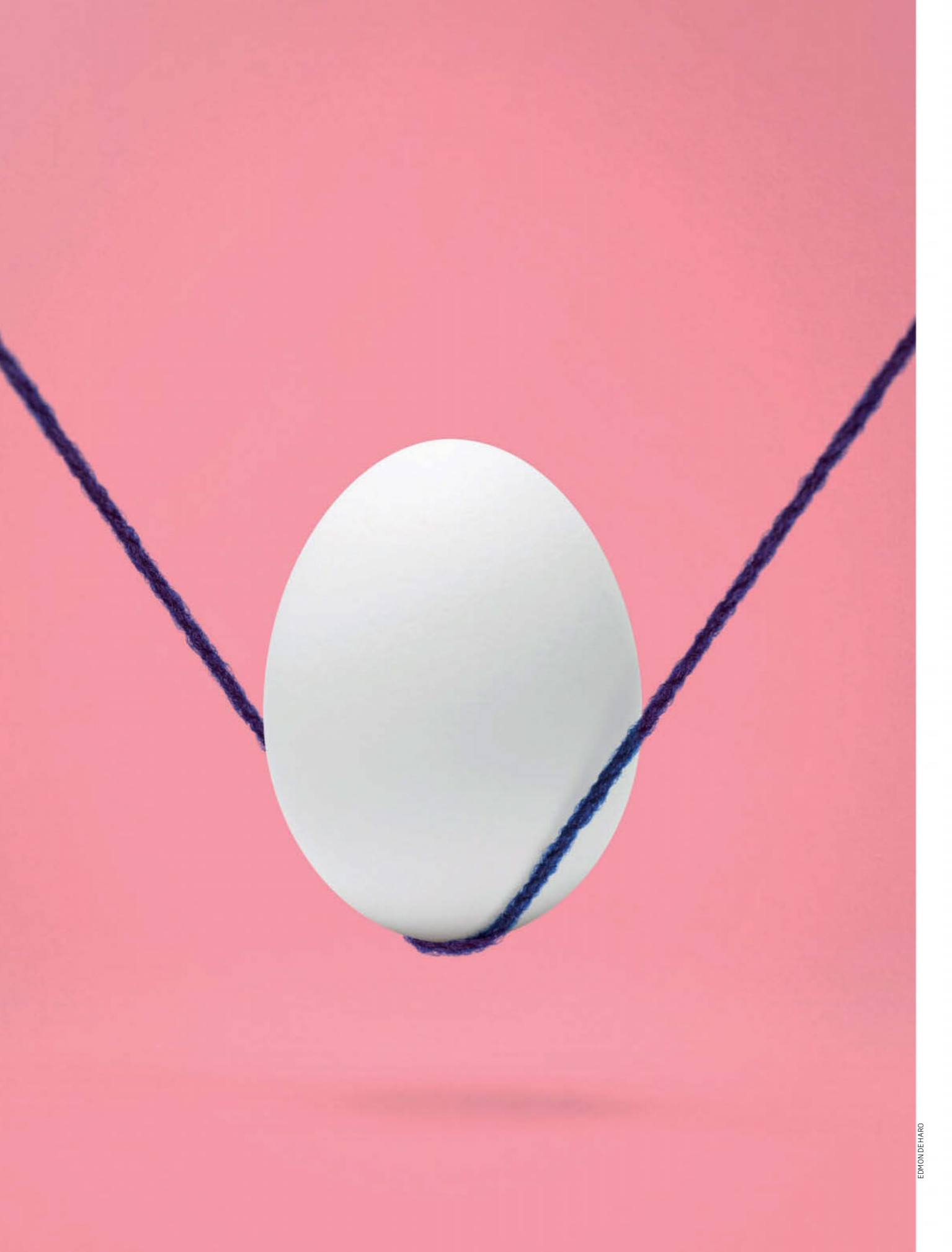
The first ever study of uncanniness and humour surfaced only last year, when Meeri Mäkäräinen of Aalto University presented a paper entitled “The Funcanny Valley” at a computer science conference in Finland. Working with Kätysyri and others, she discovered that exaggerating a person’s smile beyond realistic dimensions did not necessarily elicit a negative reaction. “When our participants saw strange faces, they smiled instead of frowning,” she says. Of course, caricaturists and the makers of latex puppets of politicians have been aware of this for some time. Clowns may be unwittingly cashing in on it too – although coulrophobia,

or fear of clowns, could mark the fine line between amusement and revulsion. And Kätysyri thinks that the living statues who grace many of our public spaces might be extracting entertainment value from the perceptual mismatch elicited when an apparently inanimate object moves.

The unbearable likeness of beings

The uncanny valley says make your avatar or robot more and more human-like in appearance and it becomes more appealing – but go too far and our reaction sinks into a trough of unease





OUR IMPLAUSIBLE UNIVERSE

The more we look at the cosmos, the stranger it becomes. Here we examine five of its unlikeliest traits – and ask what might lie behind them

MATTER AND ENERGY ARE IN BALANCE

Gilead Amit

INVISIBLE dark matter and dark energy make up around 95 per cent of the universe between them. What's more, their densities are roughly equal – a state of affairs so unlikely that cosmologists have taken to calling it the cosmic coincidence problem.

Is this a genuine conundrum? At first blush, it seems contrived. Dark matter, which gravitates like normal matter, accounts for about 27 per cent of the universe. Meanwhile some 68 per cent is dark energy, the stuff that is causing the expansion of the cosmos to speed up. Not quite so equal after all, then.

But the values are still close enough to be perplexing – and according to our standard cosmological model, the similarity is relatively new. The very early universe was dominated by dark matter. “At that time, dark matter density was 95 orders of

magnitude larger than the density of dark energy,” says Nicolao Fornengo at the University of Turin, Italy.

But dark matter's density has been dropping as the universe expands, while the density of dark energy is widely assumed to remain constant over time, making it steadily more dominant. A few billion years ago, dark energy became denser than dark matter – causing the universe's expansion to begin racing away (see “The universe is flat as a pancake”, page 35).

Still, it seems we live in a special time where neither entity is able to dominate the other. According to Andrew Pontzen at University College London, this golden age started around 3 billion years ago and will last for perhaps another 6 billion. “But if you fast forward 10 billion years or so into the future,” he says, “the matter we are made of will seem like a wisp in an overwhelmingly dark-energy-dominated universe. And that will last for the rest of time.”

Perhaps the current equilibrium is most easily explained by appealing to some form of the anthropic principle (see “Best of all possible worlds?”, page 34): our existence depends on having a planet, star and ultimately a galaxy to live in, and their existence at this time depends on the balance of dark matter and dark energy.

Or perhaps it is no coincidence. Fornengo, for one, wonders whether dark matter and

dark energy are in fact two sides of the same coin. “Like particles interact, maybe dark energy and dark matter interact,” he says. If dark energy were gradually to decay into dark matter, that would put a brake on the plummeting dark matter density, ensuring the cosmic broth never gets too dilute.

Such interactions require new cosmological models, not least because they allow the density of dark energy to change over time. “If you add these to the game, you change dramatically the evolution of the universe,” says Fornengo, generating fluctuations in its background temperature and giving rise to structures visible at the largest scales.

Data from the next generation of telescopes, peering back to the early universe, should give us a chance to see which of these models is the best fit. But at present, says Pontzen, there's nothing to suggest any deviation from the standard picture – so this remains an inexplicable coincidence.

EVERYTHING POINTS IN ONE DIRECTION

Stuart Clark

COSMOLOGISTS called it the axis of evil. Spotted in 2005 in the cosmic microwave background, the all-pervading afterglow of the big bang, the axis was a peculiar alignment of features where we would have expected nothing but randomness.

The name was justifiably melodramatic, given that it threatened our established view of the universe. At the heart of that

"This would be not just an axis of evil, but an axis of everything"

picture is the cosmological principle, which says that the universe appears the same on the largest scales no matter where you happen to be looking. This is what you'd expect in the aftermath of an explosion like our big bang, with all the constituents winding up mixed together in a randomised, homogeneous soup. The reality, it seemed, wasn't like that – and despite steadily improving measurements, the axis has stubbornly refused to vanish.

Cosmologist Jonah Miller at the University of Guelph in Ontario, Canada, is intrigued but sceptical of its significance. "Studying the axis of evil is certainly worthwhile. However, I don't believe it represents a major gap in our understanding of early-universe cosmology." He thinks the axis is just an example of what happens when you look at random data: familiar patterns will emerge by sheer chance, signifying nothing.

But it's not just the microwave ripples that seem odd. Wen Zhao, a physicist at the University of Science and Technology of China in Hefei, has been collecting a host of other observations that appear to line up with the axis of evil. They include the movement of galaxies across the universe as well as the direction in which spiral galaxies' arms curl. Not only that, but measurements of such unrelated phenomena as the temperature of the microwave background radiation, the value of the fine structure constant responsible for atomic structure, and even the acceleration of the universe's expansion also all seem to vary as we move along that axis. Most oddly of all, these alignments point in the very direction that the solar system is

moving through space.

If genuine, it's not just an axis of evil, but an axis of everything. "If they were real features of the universe, it means that the cosmological principle will be violated, which is the basis of modern cosmology," says Zhao.

Although alternative cosmologies have been proposed, most fall foul of the latest results from the European Space Agency's Planck satellite, which suggest the universe is indeed more or less homogeneous. But there's another wacky theory that chimes with the axis idea: that the universe could be rotating. Championed by Michael Longo at the University of Michigan, Ann Arbor, this rotation would impart angular momentum to galaxies as they form, helping them to spin in a preferred direction.

But the more bizarre the coincidences get, the more it suggests that something rather banal could be behind them. Zhao believes the sheer abundance of alignments shows that we must be getting something consistently wrong in our measurements. "Otherwise it is very difficult to understand why the cosmological preferred axes should coincide with the motion of the solar system," he says.

Best of all possible worlds?

PHYSICISTS dislike coincidences such as those set out on these pages, suspecting them of covering up some new principle they don't yet grasp. But when they run out of theories, there's a one-size-fits-all explanation that can answer everything without really answering much at all: the universe is as it is because we're here to see it.

This piece of circular logic is the anthropic principle. A universe inhospitable to life would have no human beings around to observe it, so the one we see must, by definition, possess features essential to accommodating intelligent life.

But that doesn't tell us whether a slightly different universe might still host life, why our particular universe exists and not some other, or why we see finely balanced features with no bearing on the emergence of life.

And yet there is an idea that sweeps all these objections away: all conceivable universes exist side by side in a patchwork multiverse. We merely inhabit one out of the infinite selection.

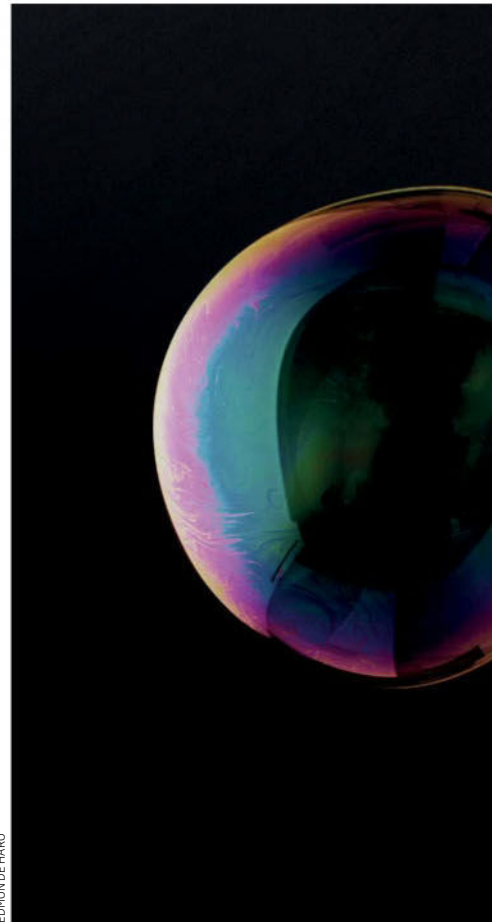
Why believe in the multiverse? Because a process such as inflation (see "The universe is flat as a pancake", right), if left unchecked, could produce a multitude of causally

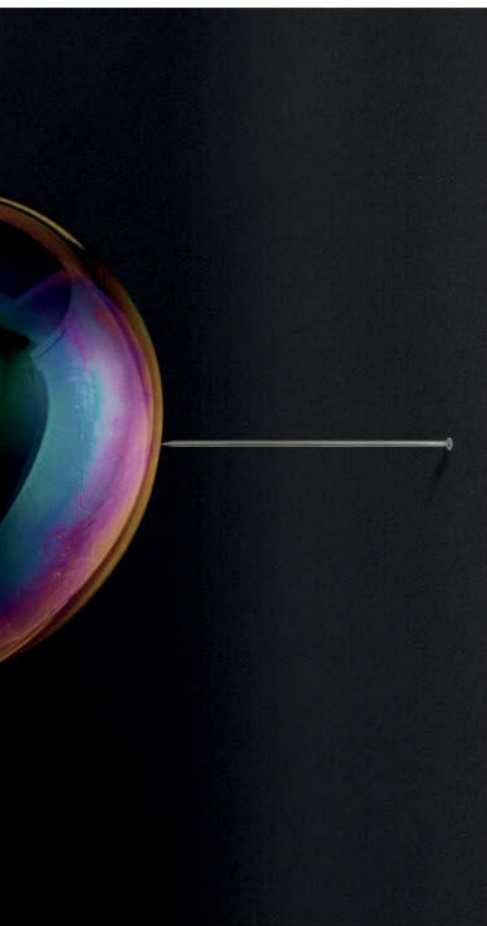
disconnected universes. String theory, still most physicists' favoured route to an overarching theory of everything, conjures up an entire landscape of maybe 10^{100} or more universes, all with slightly varying properties.

But some still see the multiverse as an abdication of scientific responsibility: a fancier way of simply saying "coincidences happen". And, if true, it means some astronomers out there are forced to justify a universe even more replete with coincidences than ours, while others could be bored stiff in a completely random cosmos.

Gilead Amit

EDMONDE HARO





THE UNIVERSE IS FLAT AS A PANCAKE

Stuart Clark

NEXT time you fancy doing something really frustrating, try balancing a pencil on its sharpened tip. Your efforts will succeed for a second at most. Yet the universe has been succeeding at a similar gravitational trick for the last 13.8 billion years.

The feat is embodied in its geometry. According to Einstein's general theory of relativity, matter and energy bend space and time, and the amount of stuff the universe contains will determine its ultimate fate. If the universe is dense enough to curve space-time in on itself, all that gravity will eventually collapse it back down to nothing. If the universe's density is low, it curves outwards – and the weakness of the gravitational pull will mean it expands forever.

But our universe seems to fit in neither camp. The most powerful test of its geometry

is the variation in the cosmic microwave background, the radiation emitted shortly after the big bang. According to measurements of this radiation, the density of matter and energy is such that the universe does not curve either way: it is perfectly flat. After an eternity, its expansion should grind to a halt with no subsequent collapse.

The plot thickened considerably in the late 1990s, when very distant exploding stars were inexplicably seen to be dimmer than expected. This suggested that the universe's expansion was accelerating rather than slowing down. The proposed fix was to say that a large proportion of the universe exists

“There is no natural candidate to explain dark energy”

as dark energy, a new ingredient allowing it to remain flat yet expand ever faster.

But devising a theory of dark energy has theorists sucking their pencils. “Progress is pretty tough going,” says Andrew Pontzen at University College London. There is no natural candidate for the phenomenon, and our best guess is that it is a vacuum energy of the sort allowed in quantum theory, resulting from particles popping in and out of existence. But simple calculations reveal that this would produce 120 orders of magnitude more dark energy than there seems to be, causing the universe to have ripped itself to pieces.

We're stuck. “Unless somebody has some amazing flash of insight, I think we are going to carry on not having a clue,” says Pontzen. But there's another possibility: that dark energy's strength has changed over time. “At that point, you're in a very different situation. You will be able to very quickly narrow down the list of what it might be.”

To break the impasse, the European Space Agency is building the Euclid telescope. Due for launch in 2020, it will map galaxies up to 10 billion light years away. By seeing how dark energy influences their arrangement and shape, the mission will be our best chance yet of seeing if its strength has changed. Only then will we begin to grasp the interplay of factors that keeps the universe so strangely flat.

IT'S ALL AT THE SAME TEMPERATURE

Stuart Clark

THE temperature of the cosmic microwave background – the radiation bathing all of space – is remarkably uniform. It varies by less than 0.001 degrees from a chilly 2.725 kelvin.

But while that might seem natural enough, this consistency is a real puzzle. For two widely separated areas of the cosmos to reach thermal equilibrium, heat needs enough time to travel from one to the other. Even if this happens at the speed of light, the universe is just too young for this to have happened.

Cosmologists try to explain this uniformity using the hypothesis known as inflation. It replaces the simple idea of a big bang with one in which there was also a moment of exponential expansion. This sudden, faster-than-light increase in the size of the universe allows it to have started off smaller than an atom, when it would have had plenty of time to equalise its temperature.

“On the face of it, inflation is a totally bonkers idea – it replaces a coincidence with a completely nonsensical vision of what the early universe was like,” says Andrew Pontzen at University College London.

Yet it seems to work. The sudden expansion would also help explain why the observable universe appears flat (see “The universe is flat as a pancake”, left). Much as the curvature of Earth only becomes visible when viewed on a large scale, space-time's complex geometry might appear flattened to observers only viewing a fraction of the whole.

What's more, it even explains how galaxies sprang up, as tiny quantum fluctuations in space blew up to form their gravitational seeds.

But not everyone is a fan. “Although the inflationary paradigm is in good agreement with data, it suffers from some conceptual problems,” says Robert Brandenberger at McGill University in Montreal, Canada.

The chief snag is that no one can find a mechanism in established physics that could trigger inflation. “There are many toy models of inflation,” says Brandenberger, but it is unclear whether any of them have a solid theoretical basis.

To kick-start inflation, something needs to put a tremendous amount of energy into the vacuum. The culprit may be a process known as baryogenesis, which was responsible for bringing more matter than antimatter into being – but as no one knows exactly how it

took place, this remains little more than a guess. And even if we can identify the trigger, working out why inflation didn't carry on forever has also proved beyond us.

To Pontzen, however, inflation is worth sticking with because it fits the data. "That's about the best criteria we have for judging a theory," he says.

But there's another contender that cosmologists have been considering: a variable speed of light. If we assume that light travelled much faster in the past, then heat could have been transferred between remote reaches of the universe in time to equalise their temperatures. The trouble is that, since we measure light's speed as a constant today, its value must either be decreasing at an ever slower rate, or have ceased to change some time ago. But as with inflation, no one can find a theoretical reason for such perplexing behaviour.

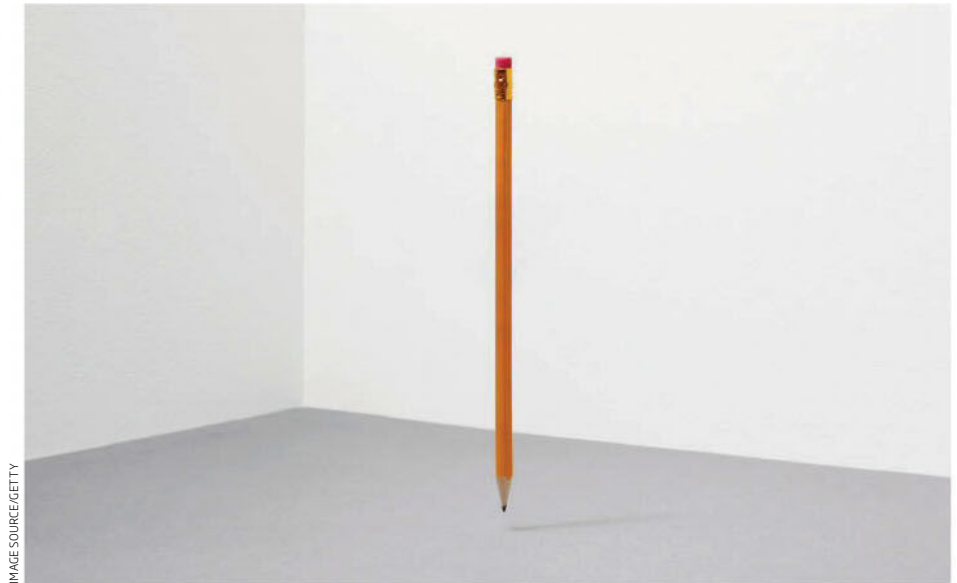


IMAGE SOURCE/GETTY

THE UNIVERSE IS ON THE BRINK OF CATASTROPHE

Anil Ananthaswamy

OUR universe has been around for nearly 14 billion years, but it could vanish in the blink of an eye.

That's because the fabric of space-time might be in a state of precarious stability – what physicists call a false vacuum – and could collapse at any moment, taking us with it. "If a bubble of true vacuum appeared near us in the universe and expanded to include us, we'd all be very, very dead," says Sean Carroll, a theoretical physicist at the California Institute of Technology in Pasadena.

The key to understanding how stable the vacuum is rests with the Higgs boson and its associated field, which pervades all of space-time and gives elementary particles their mass. In July 2012, physicists at the Large Hadron Collider (LHC) in Geneva, Switzerland, finally sighted the Higgs boson and pegged its mass to somewhere between 125 and 127 gigaelectronvolts.

Although elementary particles get their masses by interacting with the Higgs field, the mass of the Higgs boson depends on those particles as well. The heaviest of these, the top quark, has the biggest impact on the Higgs mass. And based on the most recent measurements of both their masses, physicists can now use the properties of the Higgs field to deduce the state of the vacuum

of space-time. The news isn't great: our universe could be on the brink.

Like a ball rolling down a hill, the vacuum will eventually come to rest in the lowest possible energy state. If there's a small trough halfway down, however, the ball could get caught. The ball would have a kind of stability, but also the potential to roll further down.

It seems we're in just such a trough (see diagram). "If the Higgs mass and the top quark mass were a little bit different, we would either be in a completely stable vacuum or in an unstable vacuum that would have decayed a

long time ago," says Carroll. "Interestingly, the world seems to be on an edge. We don't have enough precision to say whether our vacuum is stable or not."

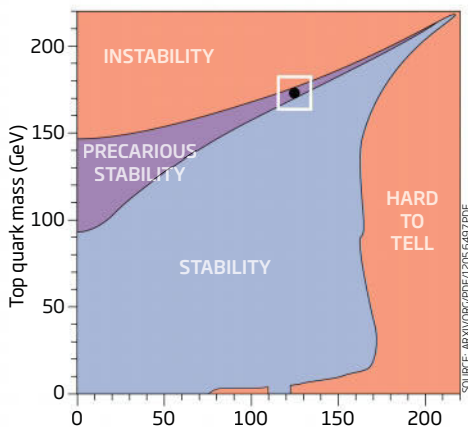
The root of the problem lies in the equation used to predict the Higgs mass, which gives a higher value than has been measured. To fix this, physicists must make the terms relating to the elementary particles' interactions with the Higgs cancel out to a remarkable degree of precision – remarkable, that is, unless something unobserved is pulling the strings. That's one rationale behind the theory of supersymmetry, a long-favoured way of avoiding such fine-tuning. Supersymmetry doubles the entries in the standard model of particle physics by giving each particle a heavy superpartner, cancelling out the terms in the equation as required. But the LHC has seen no hints of these superpartners, casting serious doubts on the theory.

These doubts have reignited interest in another hypothetical particle called the axion, which new calculations show can interact with the Higgs and the top quark so as to prevent the Higgs mass from ballooning. The axion was originally proposed to solve other problems with the standard model, but its ability to multitask makes it a hot target.

If no axion turns up, however, we might be forced to turn to the multiverse for salvation. In a reality filled with infinite universes, each with its own set of particles of arbitrary masses, living in an implausibly fine-tuned universe becomes a lot more likely. ■

Massive coincidence

If the top quark were slightly heavier relative to the Higgs boson, the universe would have collapsed long ago

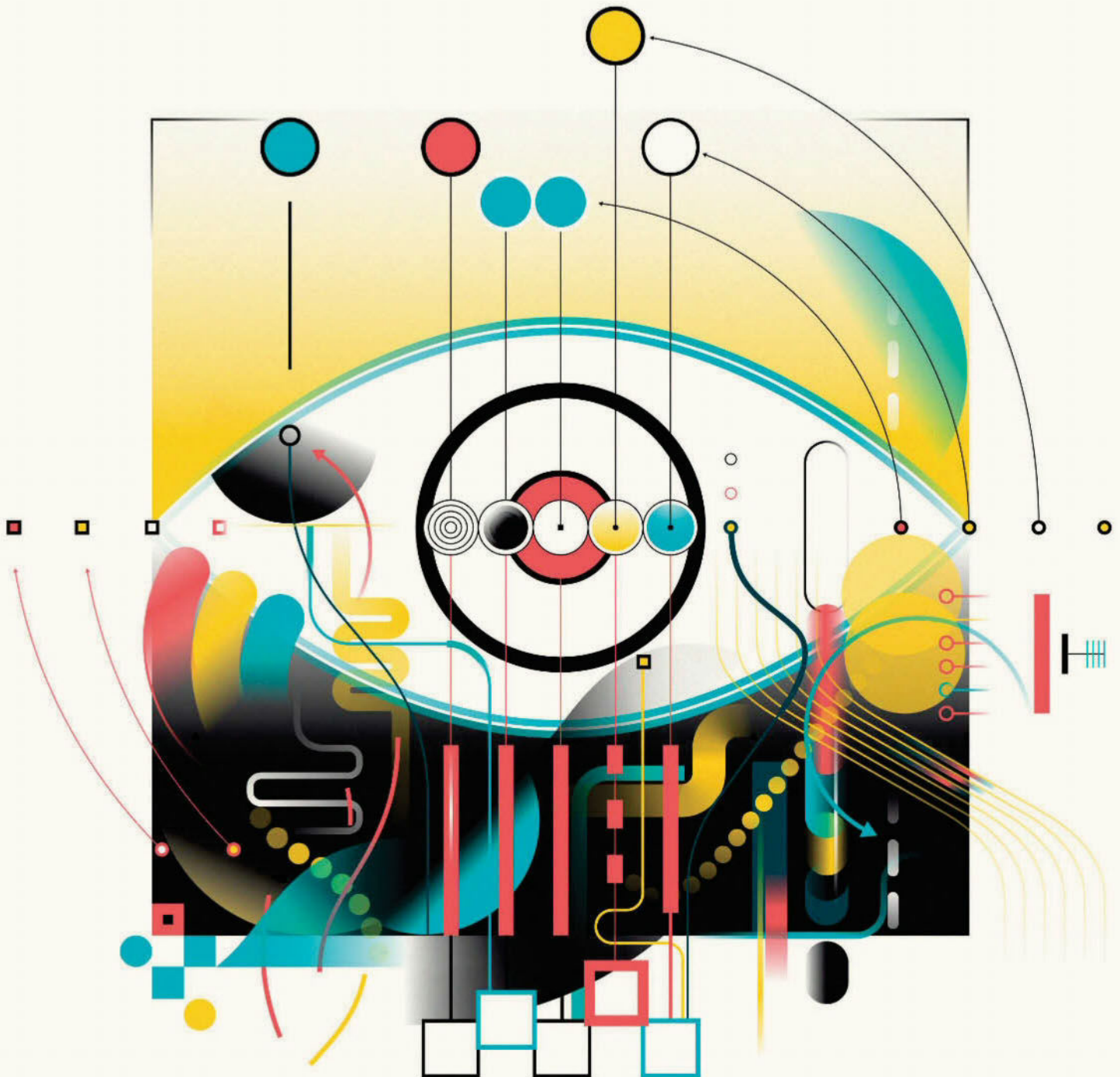


SOURCE: AXIOM/CPDF/2015.649/731F

ARTIFICIAL INTELLIGENCE PART ONE

Computers that could simulate human intelligence were once a futuristic dream. Sixty years on, they are all around us - but not in the way their pioneers expected

Illustrations by Leandro Castelao



INTELLIGENCE REINVENTED

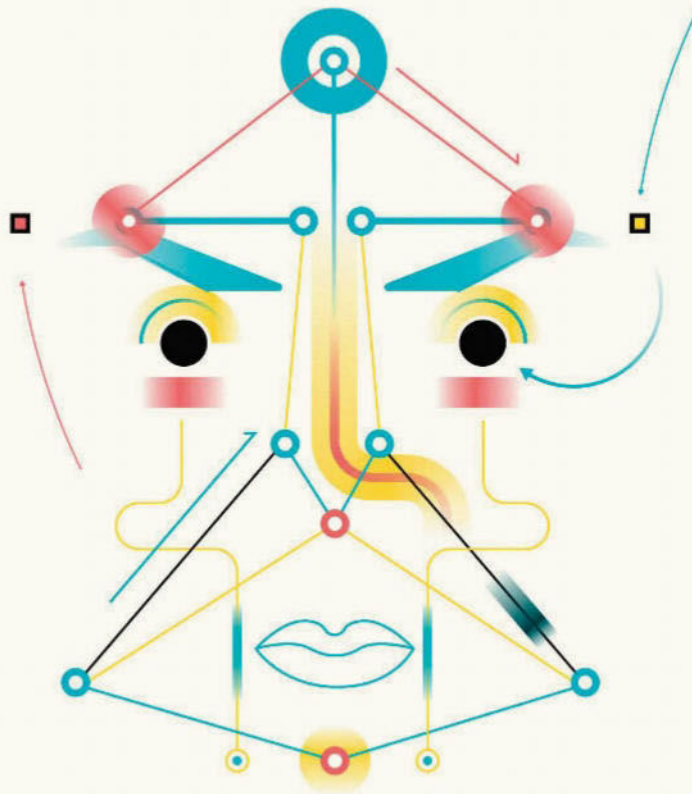
The arrival of artificial intelligence in our lives is a story of hype, disappointment and unexpected triumph, explains Nello Cristianini

IN the summer of 1956, a remarkable collection of scientists and engineers gathered at Dartmouth College in Hanover, New Hampshire. Among them were computer scientist Marvin Minsky, information theorist Claude Shannon and two future Nobel prizewinners, Herbert Simon and John Nash. Their task: to spend the summer months inventing a new field of science called “artificial intelligence” (AI).

They did not lack in ambition, writing in their funding application: “every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it.” Their wish list was “to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves”. They thought that “a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer.”

It took rather longer than a summer, but 60 years and many disappointments later, the field of AI seems to have finally found its way. In 2016, we can ask a computer questions, sit back while semi-autonomous cars negotiate traffic, and use smartphones to translate speech or printed text across most languages. We trust computers to check passports, screen our correspondence and fix our spelling. Even more remarkably, we have become so used to these tools working that we complain when they fail.

As we rapidly get used to this convenience, it is easy to forget



that AI hasn't always been this way.

At the Dartmouth conference, and at various meetings that followed it, the defining goals for the field were already clear: machine translation, computer vision, text understanding, speech recognition, control of robots and machine learning. For the following three decades, significant resources were ploughed into research, but none of the goals were achieved. It was not until the late 1990s that many of the advances predicted in 1956 started to happen. But before this wave of success, the field had to learn an important and humbling lesson.

While its goals have remained essentially the same, the methods of creating AI have changed dramatically. The

instinct of those early engineers was to program machines from the top down. They expected to generate intelligent behaviour by first creating a mathematical model of how we might process speech, text or images, and then by implementing that model in the form of a computer program, perhaps one that would reason logically about those tasks. They were proven wrong.

They also expected that any breakthrough in AI would provide us with further understanding about our own intelligence. Wrong again.

Over the years, it became increasingly clear that those systems weren't suited to dealing with the messiness of the real world. By the early 1990s, with little to show for decades of work, most engineers

started abandoning the dream of a general-purpose top-down reasoning machine. They started looking at humbler projects, focusing on specific tasks that were more likely to be solved.

Some early success came in systems to recommend products. While it can be difficult to know why a customer might want to buy an item, it can be easy to know which item they might like on the basis of previous transactions by themselves or similar customers. If you liked the first and second Harry Potter films, you might like the third. A full understanding of the problem was not required for a solution: you could detect useful correlations just by combing through a lot of data.

Could similar bottom-up shortcuts emulate other forms of intelligent behaviour? After all, there were many other problems in AI where no theory existed, but there was plenty of data to analyse. This pragmatic attitude produced success in speech recognition, machine translation and simple computer vision tasks such as recognising handwritten digits.

DATA BEATS THEORY

By the mid-2000s, with success stories piling up, the field had learned a powerful lesson: data can be stronger than theoretical models. A new generation of intelligent machines had emerged, powered by a small set of statistical learning algorithms and large amounts of data.

Researchers also ditched the assumption that AI would provide us with further understanding of our own intelligence. Try to learn from

Nello Cristianini is professor of artificial intelligence at the University of Bristol, UK

algorithms how humans perform those tasks, and you are wasting your time: the intelligence is more in the data than in the algorithm.

The field had undergone a paradigm shift and had entered the age of data-driven AI. Its new core technology was machine learning, and its language was no longer that of logic, but statistics.

How, then, can a machine learn? It is worth clarifying here what we normally mean by learning in AI: a machine learns when it changes its behaviour (hopefully for the better) based on experience. It sounds almost magical, but in reality the process is quite mechanical.

THE WINTERS OF AI DISCONTENT

Emergent technologies are often subjected to hype cycles, sometimes due to speculative bubbles inflated by excessive investor expectations. Some examples are railway mania in the UK in the 1840s and the dot-com bubble in the 1990s.

Artificial intelligence is perhaps unique in having undergone several hype cycles in a relatively short time. Its slumps of optimism even have a specific name: AI winters (see timeline, right). The two major winters occurred in the early 1970s and late 1980s. Both were caused largely by the withdrawal of public funding as progress stalled.

AI is now in a renewed phase of heightened optimism and investment. Unlike in previous cycles, however, AI today has a strong - and increasingly diversified - commercial revenue stream. Only time will tell whether this turns out to be a bubble.

Consider how the spam filter in your mailbox decides to quarantine some emails on the basis of their content. Every time you drag an email into the spam folder, you enable it to estimate the probability that messages from a given recipient or containing a given word are unwanted. Combining this information for all the words in a message allows it to make an educated guess about new emails. No deep understanding is required – just counting the frequencies of words.

But when these ideas are applied on a very large scale, something surprising seems to happen: machines start doing things that would be difficult to program directly, like being able to complete sentences, predict our next click, or recommend a product. Taken to its extreme conclusion, this approach has delivered language translation, handwriting recognition, face recognition and more. Contrary to the assumptions of 60 years ago, we don't need to precisely describe a feature of intelligence for a machine to simulate it.

While each of these mechanisms is simple enough that we might call it a statistical hack, when we deploy many of them simultaneously in complex software, and feed them with millions of examples, the result might look like highly adaptive behaviour that feels intelligent to us. Yet, remarkably, the agent has no internal representation of why it does what it does.

This experimental finding is sometimes called “the unreasonable effectiveness of data”. It has been a very humbling and important lesson for AI researchers: that simple statistical tricks, combined ➤

- 1950 Alan Turing publishes the seminal paper “Computing machinery and intelligence”. Its opening sentence is “I propose to consider the question, ‘Can machines think?’”
- 1956 The term “artificial intelligence” is coined at a workshop at Dartmouth College
- 1959 Computer scientists at Carnegie Mellon University create the General Problem Solver (GPS), a program that can solve logic puzzles
- 1973 The first AI winter sets in as funding and interest dry up
- 1975 A system called MYCIN diagnoses bacterial infections and recommends antibiotics using deduction based on a series of yes/no questions. It was never used in practice
- 1987 Second AI winter begins
- 1989 NASA's AutoClass computer program discovers several previously unknown classes of stars
- 1994 First web search engines launched
- 1997 IBM's Deep Blue beats world champion Garry Kasparov at chess
- 1998 NASA's Remote Agent is first fully autonomous program to control a spacecraft in flight
- 2002 Amazon replaces human product recommendation editors with an automated system
- 2007 Google launches Translate, a statistical machine translation service
- 2009 Google researchers publish an influential paper called “The unreasonable effectiveness of data”. It declares that “simple models and a lot of data trump more elaborate models based on less data” (IEEE Intelligent Systems, vol 2, p 8)
- 2011 Apple releases Siri, a voice-operated personal assistant that can answer questions, make recommendations and carry out instructions such as “call home”
- 2011 IBM's supercomputer Watson beats two human champions at TV quiz game Jeopardy!
- 2012 Google's driverless cars navigate autonomously through traffic
- 2016 Google's AlphaGo defeats Lee Sedol, one of the world's leading Go players

“Modern artificial intelligence is a brilliant and powerful technology, but also a fundamentally disruptive one”

with vast amounts of data, have delivered the kind of behaviour that had eluded its best theoreticians for decades.

Thanks to machine learning and the availability of vast data sets, AI has finally been able to produce usable vision, speech, translation and question-answering systems. Integrated into larger systems, those can power products and services ranging from Siri and Amazon to the Google car.

Researchers' attention is now focused what fuels the engine of our intelligent machines: data. Where can they find data, and how can they make the most of this resource?

One important step has been to recognise that valuable data can be found freely “in the wild”, generated as a byproduct of various activities – some as mundane as sharing a tweet or adding a smiley under a blog post.

Engineers and entrepreneurs have also invented a variety of ways to elicit and collect additional data, such as asking users to accept a cookie, tag friends in images, rate a product or play a location-based game centred on finding monsters in the street. Data became “the new oil”.

At the same time as AI was finding its way, we developed an unprecedented global data infrastructure. Every time you access the internet to read the news, do a search, buy something, play a game, or check your email, bank balance or social media feed, you interact with this infrastructure. It isn't just a physical one of computers and wires, but also one of software, including social networks and microblogging sites.

Data-driven AI both feeds on this infrastructure and powers it – it is hard to imagine one without the other. And it is hard to imagine life without either of them.

CHALLENGES AHEAD

This is what makes modern AI a brilliant and powerful technology, but also a fundamentally disruptive one.

The unified data infrastructure is not like any medium invented before. Unlike the copper cables that used to connect people in the telegraph or telephone age, it takes a keen interest in our actions. The medium looks back at us, anticipating our moves, guessing our intents, often trying to serve us better and sometimes to influence us. This gives a whole new meaning to the claim, made by the 1970s communications

theorist Marshall McLuhan, that a medium can never be neutral.

The challenges AI might present us with include surveillance, discrimination, persuasion, unemployment and possibly even addiction. Are we prepared?

Intelligent machines need to collect data – often personal data – in order to work. This simple fact potentially turns them into surveillance devices: they know our location, our browsing history and our social networks. Can we decide who has access, what use can be made of the data, or whether the data gets deleted for ever? If the answer is no, then we don't have control.

AI's capability to make predictions is useful for insurance, loans and policing. But the quality of those predictions will depend on subtle design choices and on the way the information used to

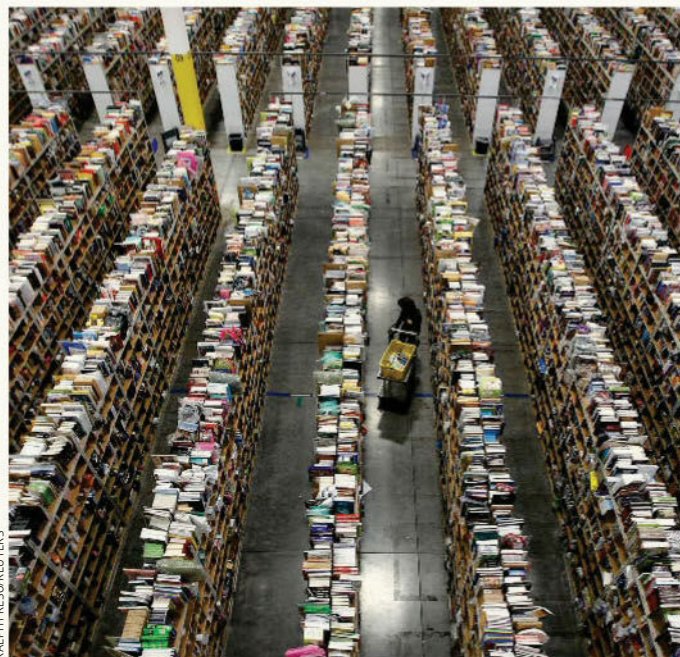
train it is collected, which creates a very real risk of implicit and unintended discrimination.

A recent investigation by ProPublica, for example, claims to have uncovered a bias that would disadvantage African Americans in the software used in many US courts to make parole decisions. Another case has been reported where different job ads were targeted at different ethnic groups. Both starkly illustrate the unintended effects of the complex interaction between algorithms and data.

Another concern is persuasion. The business model of many AI companies is advertising, which means getting people to click on specific links. Research on how to steer users is well under way. The more the machines know about us, the better the job they can do of nudging us. Predictive interfaces might even induce addiction in vulnerable users, by actively rewarding them with the juiciest content that the web has to offer. This is something that needs to be carefully studied.

Employment will be affected too, as AIs learn from us (quite literally) how to do certain jobs, either because they watch how we do them, or because we are paid to generate their training data.

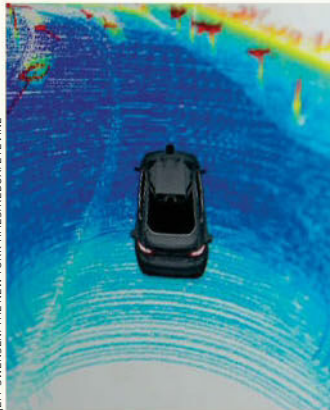
The emergence of internet crowdsourcing allows businesses to automatically outsource micro-tasks that require human intelligence, by posting them on websites or apps where workers can choose the tasks they want to accept. In a way this works just like Uber, but for tasks other



RALPH FRESO/REUTERS

AI will increase the automation of warehouses like Amazon's

Coming soon: the second half of our Instant Expert on artificial intelligence, in which Nello Cristianini delves deeper into the technology that allows machines to learn



JEFF SWENSEN/THE NEW YORK TIMES/REDDUX/EVINE

Driverless cars “see” better than ever, but mistakes can’t be ruled out

than driving, and is mediated by a computer system. Typical tasks would include transcribing handwriting or labelling images.

This also creates a workforce directly managed via computers, and defines a set of tasks that are the ideal candidate for automation. Indeed, many of those task-workers are actually generating or annotating the data being used to train their AI replacements.

At the same time, we can expect many call centres and warehouses to be increasingly automated within a decade.

I do not believe that we yet have the legal and cultural tools to handle these and many other challenges. Who do we turn to if an intelligent algorithm denies us parole, medical treatment or a diploma? Are we prepared for our character and trustworthiness to be ranked just like our credit history, as some countries are proposing? Do we want the state to have access to our online activities and knowledge of our preferences? Do we want our children to spend their online time in the company of

persuasive machines, designed to steer their behaviour in a given direction? What happens to society if large numbers of people are put out of work?

Artificial intelligence has come a long way from its early days in academic laboratories. It is now being integrated into our lives, and promises to improve them. We might not call it AI once it is deployed, but we can expect benefits in fields ranging from healthcare to transportation, from communications to schooling.

And research is not slowing down. The machine-learning paradigm has been effective in addressing many areas like vision and speech processing, and it is likely that future AI will also find a way to integrate some top-down reasoning methods descended from earlier approaches. What will come after that may surprise us again.

As our AI efforts continue to open up new possibilities, we can imagine seamless conversations with machines, fluent real-time translation of speech, and many useful ways to automate our houses and cars.

But we might want to resist the temptation to introduce AI into as many domains as possible, at least before the cultural and legal framework evolves. Widespread adoption of AI brings remarkable opportunities, but also potential risks. Contrary to popular belief these are not existential risks to our species, but rather a possible erosion of our privacy and autonomy.

So as we finally enjoy the benefits of six decades of research in AI, with machines joining us in our everyday lives, we should celebrate – but also tread carefully. ■

YOU WIN SOME...



BEN HIGER/BETTY

One of the most celebrated successes of machine learning (see main story) came earlier this year when an algorithm called AlphaGo defeated South Korean master Lee Sedol at the game Go – something none of its programmers could come close to doing themselves. AlphaGo combined various machine-learning methodologies to analyse databases of more than 30 million Go moves, as well as playing thousands of games against itself. A similar strategy earlier allowed IBM's Watson supercomputer to win at the TV quiz game Jeopardy! (pictured above).

Given the right data, it seems that machines can improve their intelligence a great deal. But we should remember that machine learning is a statistical exercise, and therefore it can always fail.

In recent years we have also seen some blunders caused by machine learning. Last year Google apologised after one of its products automatically labelled photos of two black people “gorillas”; this year Microsoft had to withdraw a conversational bot called Tay because it had learned offensive language. In both cases it was not a failure of the algorithm, but of the training data that had been fed to it.

This year also saw the first fatality linked to a “driverless” car, when a driver put a Tesla on autopilot and it failed to detect a trailer on the road. The conditions were unusual, with a white obstacle against a light sky, and the computer vision system simply made a mistake. I do not expect it to be the last one as many companies move into that market.

On the other hand, there are countless stories that do not end up in the news, simply because the AI systems are doing their work as expected. They include search engines, online shops and semi-autonomous cars.

As we entrust machines with increasingly sensitive decisions, we need to pay careful attention to the kind of data we feed to them. It is not just the technology, but its deployment in our everyday life, that needs better understanding.

The autistic mouse and other unlikely stories

Genetically modified animals are used to model all kinds of human conditions and diseases, but they're not helping us find many treatments or new drugs. **Joseph Garner** has an idea why

Why does drug development using animals need a rethink?

I think we've got ourselves into a mess right now, with lab mice in particular. The benefits to humans, in certain diseases and mouse models, have shrunk to such low levels that it's time we found better ways to work with animals in medical research.

How have the benefits to humans shrunk?

Of the drugs that get past the animal testing phase and into human trials, only about 1 in 9 actually make it to the market, and that's dropping all the time. It costs about \$2 billion to bring a single drug to market, largely because of failed human trials. And they usually fail simply because the drug doesn't work, or not as well as animal testing predicted.

Why isn't research translating well from animals to humans?

The idea is that the animal model will tell you something about how this drug is going to perform in humans. But we have to ask ourselves, are these animals truly modelling the human disease? Increasingly, they are not. So we end up learning a great deal about how mice respond to various compounds, but it's irrelevant to humans and an enormous waste of money.

We need to do animal research that actually translates well. A knock-on effect of that will be that these drugs fail earlier in the development process, before the cost of failure skyrockets.

So what's the underlying issue?

There are several, but in drugs for cognitive conditions, the single biggest issue is the use of the word "like". We describe mouse models

as OCD-like, autism-like, Alzheimer's-like, and so on. This happens for well-intentioned reasons: scientists are flagging up that they're not sure whether these traits in their animals really represent the condition in humans. But it only takes four or five other research groups to follow suit and, lo and behold, although we still don't know if this OCD-like mouse model usefully represents OCD, you are not allowed to point that out any more – the emperor has no clothes.

Taking autism as an example, why doesn't research in mice translate well?

To be diagnosed with autism, you have to show some behaviours and, crucially, not others. It's largely a diagnosis of exclusion: kids with autism have problems with imaginative social play; they have real trouble with theory of mind – that is, being able to understand the private emotional lives and knowledge of other people – and they often don't make eye contact.

Now, it's pretty hard to figure out whether a mouse is making eye contact, there is no behaviour in mice that we really understand as being play, and mice are not on the very short list of species shown to have a theory of mind. So it's bonkers to think that the social issues of autism are measurable in mice, yet researchers claim to be finding them. Put simply, you can't model the absence of something in a species that doesn't have it in the first place.

How has genetic engineering altered our animal models?

We see researchers "disorder-shopping": they genetically engineer a mouse with an unusual behavioural or physical trait, then tout it

PROFILE

Joseph Garner is an associate professor of comparative medicine at Stanford University, California, with a focus on why most drugs (and basic science findings) fail to translate to human outcomes

around to researchers until someone bites. For example, there's a GM mouse model called D1CT-7, which has been heavily marketed. These mice have spontaneous tics and they are classed as Tourette's-like, not to mention anxiety-like and OCD-like. Yet it isn't a true model of Tourette's syndrome because the part of the mouse brain causing its Tourette's-like behaviour is not the part of the brain that is central to Tourette's in people.

Do you take issue with experimental methods more generally?

Certainly. Just think about what it would mean if a human experiment were comparable to a mouse experiment. We would be using a population of nothing but 42-year-old white males that live in identical ranch homes in some small town somewhere with identical diets, identical wives, identical children, identical furniture; they eat the same thing





STEVE FISCH/STANFORD SCHOOL OF MEDICINE

every day for every meal, the thermostat is locked, and the gardener is an extremely scary-looking *Tyrannosaurus rex* that pulls the roof off their house once a week and destroys their Facebook account and all of their social information. Just take it as far as you want to go because it is such a crazy way to design an experiment that's meant to shed light on humans.

Good experimental design involves controlling for confounding factors, but the only place where we try to do that by making every individual identical is lab animal work, and particularly mouse work. These are Stepford mice! It's the only field of biology or psychology where we don't recognise that

"It's bonkers to think that the social issues of autism are measurable in mice"

variation is what makes us special, what makes us interesting – and what makes us ill.

How has this line of thinking changed the way you conduct your own experiments?

It's little use manipulating animals, by genetic engineering or otherwise, so that they simulate the symptoms of conditions they don't really have. So what's the antidote? The secret is to really start looking for animals that spontaneously get ill or display unusual behaviour, and then ask why. My collaborative research on autism has led us to work with very, very large colonies of free-living primates, identifying the socially unusual individuals and asking, are these individuals behaving in ways that make sense in terms of autism? Are they showing the same biological markers that we have found in children with autism? The answer is "watch this space" – I can't give specifics until the work is published.

What about the work you do with mice?

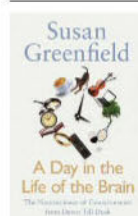
Mice are furry little time machines. I can actually follow a mouse from before its conception through to its death in a year or two, and I can see which animals become spontaneously ill and which ones don't, and measure the processes that I think might be involved. That illness might be diabetes, mammary cancer, compulsive hair-pulling, or whatever condition I happen to be interested in. Because the minute you start looking for spontaneous illness in this way, you're suddenly just in the world of human research methods, your animals are happier, research is more likely to translate to humans, and a lot of the problems associated with animal research simply disappear. That's good science, good animal welfare, and good business too. ■

Interview by Aviva Rutkin

What makes us conscious?

Anil Ananthaswamy explores the hardest of hard problems

A Day in the Life of the Brain: The neuroscience of consciousness from dawn till dusk by Susan Greenfield, Allen Lane, £20



“SMALL wonder that the black night outside your bedroom window is as nothing compared to the intellectual darkness that gives

rise to this conceptual impasse.” This impasse is the so-called hard problem of consciousness: how does a material brain give rise to a seemingly immaterial conscious experience? And the author introducing it so poetically is Susan Greenfield in her new book, *A Day in the Life of the Brain*.

Thankfully, after a number of books in which Greenfield claimed – without any convincing evidence – that our technologies were changing human brains for the worse, she is back in the realm of normal, empirical science.

Her new book, while flawed, is a definite improvement on its predecessors. It is prefaced by a hurried tour of the big ideas and theories about consciousness, which may prove hard going for readers unfamiliar with the terrain. Her point, however, is that so far no approach has brought us any closer to understanding how philosopher Colin McGinn’s “water” of objective neural activity turns into the “wine” of subjective conscious experience.

The book’s promise is of a better way to tackle the hard problem. Greenfield takes everyday experiences of being conscious – waking up, having breakfast, working, coming home, sleeping and dreaming – to explore what



MICHAEL CHRISTOPHER BROWN/MAGNUM PHOTOS

the brain is doing, and to see what general principles emerge that can shed light on consciousness.

In the chapter on waking, she points out that consciousness is not an all-or-nothing event. Just as we fade into unconsciousness during anaesthesia, we come into consciousness by degrees.

This is hard to explain using the activity of the brain at either the micro level of individual neurons or the macro level of, say, the frontal cortex. Better, says Greenfield, to look to an intermediate scale – neuronal assemblies, the “collective activity of brain cells that expand or diminish from one moment to the next to accommodate varying

depths of consciousness”.

Consciousness, the idea goes, is determined by these transient assemblies, whose sizes and durations are influenced by such factors as the strength of external stimuli, cognitive associations for a given stimulus, and the level of neurotransmitters and hormones in brain and body.

The problem is that Greenfield can use the word “consciousness” in a confusing way, and fails to distinguish clearly between the contents of consciousness and consciousness itself. For example, she discusses the first moments of waking, when we are still warm under the duvet – “simple, passive consciousness” – and how that progresses to thinking about the rest of the day. She writes “Your consciousness has undoubtedly ‘deepened’ or ‘grown’ in some way”, but one

Does our consciousness “grow” as we wake up and take on the day?

could equally argue that only the contents of consciousness have changed, from an awareness of being under the duvet to the awareness of one’s life story.

The structure of the book is a bit contrived, permitting Greenfield many fascinating digressions that may, or may not, relate to consciousness. In the chapter on breakfast, she points out that the meal is a time when our senses are overactivated – taste, sight, smell and sound are “commandeering your consciousness”. Greenfield then segues into a discussion of how the brain processes sensations, synaesthesia, pheromones and the effect of music on the brain.

Later, the chapter on being at the office deals with colour

“Schizophrenia may be the outcome of a brain more like a child’s, lacking high-level cognitive control”

perception, surely little to do with our drab offices? In fact, the chapter is about the psychology of creativity and identity. And why, in 2016, does Greenfield address a male reader, going home to find “wife, son and mother-in-law” waiting for him?

That aside, there is much good here. Her writing is clear, sharp, devoid of difficult jargon and chatty. The brain’s complexity comes across vividly, and its achievements are a marvel. The neuronal assemblies yield interesting insights, too. To understand the contents of our consciousness, we need to study how these assemblies form, how big they get and how they compete, she says. One practical insight could lie in schizophrenia, which, Greenfield speculates, is the outcome of a brain more like a child’s, highly responsive to stimuli, dominated by the here and now, but lacking high-level cognitive control. Such a brain can only create small assemblies that turn over fast.

However, as she acknowledges, invoking neuronal assemblies to explain conscious experience doesn’t tell us why their activity results in consciousness. An individual assembly cannot be a neural correlate of consciousness, because each one starts to decay after a few hundred milliseconds, while consciousness does not. The hard problem persists.

Her solution is a “meta-assembly” that gives rise to consciousness, and responds to smaller assemblies that form and dissipate. But she passes the buck: this would be some kind of neuronal “space-time manifold”, she says, and a meta-assembly “is more likely to be described ... by theoretical physicists than by neuroscientists”.

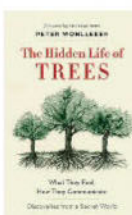
Physicists, of course, would have told you that anyway: for them, it all comes down to physics in the end. ■

Anil Ananthaswamy is a consultant for *New Scientist*

Life in the slow lane

Will we go tree-watching one day, asks **Sandrine Ceurstemont**

The Hidden Life of Trees: What they feel, how they communicate – discoveries from a secret world by Peter Wohlleben, Greystone Books, £16.99



TREES may have vibrant inner lives that aren’t so different from ours. They thrive in families, form underground social networks and may even feel pain. What’s more, they seem to have individual personalities, benefit from a good night’s sleep and communicate using different types of language.

Or so claims Peter Wohlleben in his bestseller, *The Hidden Life of Trees*, newly translated from German. His insight is based on working as a forester in Germany. “I’ve been watching trees for the past 25 years and living with them all day long,” he told me.

By talking to tree scientists

Explaining trees’ lives in human terms is seductive but risky

from the nearby University of Aachen and reading academic papers, Wohlleben gained a better understanding of what he was witnessing. As a nature enthusiast, however, most of the insights he presents have not been subjected to the same scrutiny as scientific research, so may be more of a jumping-off point for further investigation.

One problem with studying trees is that they live life in the slow lane, so it takes a lot of time, and close observation, to uncover their “behaviour”. Being able to simply spend time around them,

“Trees thrive in families, form underground social networks and may even feel pain”

as Wohlleben did, is a good way to make accidental discoveries.

His most memorable encounter involved what he thought were strangely shaped stones covered in moss. After picking off some of the greenery, he was surprised to find that it was old wood that had become hard as rock, and formed

part of a gnarled tree stump that appeared to be hundreds of years old. But a greenish layer under the bark indicated that it was still alive. “The only possibility was that it was connected to its neighbours’ roots, which were sending it sugar to keep it alive,” he says.

Wohlleben’s anecdotes are engaging, but sadly his book contains only a few. For the most part, it jumps around a tree’s life, using anthropomorphic language to explain various aspects. This may help laypeople relate to trees, but when he hints that humans might be able to communicate with plants given that seedlings respond to sound, we have strayed into oversimplification.

The book’s goal, however, is to bring tree conservation centre stage. When Wohlleben started his career, he worked for the forestry commission, where the focus was on optimising lumber production. This meant the trees’ life cycles were speeded up, while the widely spaced planting prevented them from developing the underground connections that they normally would have done. It was only when Wohlleben started organising forest tours that he discovered the natural processes being disrupted.

In the next 10 years, Wohlleben hopes concern for animal rights will lead to similar rights for trees, and forestry practices will become more sustainable. As he says, “Trees are often seen as oxygen producers or raw material for the timber industries. Maybe one day people will also enjoy watching trees as much as elephants.”

Sandrine Ceurstemont is a writer based in Morocco



JAMES BALOG/ARND BRONKHORST

A world transformed

Chris Baraniuk welcomes a cleverly naive tour of the internet by a legendary film-maker

Lo and Behold: Reveries of the connected world by Werner Herzog, at UK cinemas now

ON 29 October 1969, the internet woke up. Scientists in a room at the University of California, Los Angeles, tried to send the word “login” to colleagues at the Stanford Research Institute. But they were only able to transmit two letters before the system crashed: “lo”. That haphazard genesis story is where Werner Herzog finds the name for his documentary about how the internet has changed humankind – *Lo and Behold*.

Curiously, the film has been paid for by a US cybersecurity company, and the project, like its subject, is a little bizarre. Herzog, who does not commonly carry a cellphone or have a Facebook account, is described in the press notes as being like “an alien visiting from another planet”.

As you watch, you sense that Herzog felt this foreignness was crucial to exposing what the internet has done to us. Everyone interviewed in the film has a different perspective; collectively, they are all still coming to terms with it. Herzog, immune from the hand-wringing, simply asks questions and makes the odd humorous comment in his voice-overs. As a format, it is messy but just about works.

There are other, slightly sharper documentaries about the internet. Consider *We Live in Public*, about a man who decides to broadcast his life online, or *The Internet's Own Boy*, about scholar and activist Aaron Swartz, who downloaded

millions of journal articles, was investigated by the FBI and later committed suicide. But those films are about specific people who happened to live during the internet era. Herzog's film is about the era itself.

He touches on familiar fears of technological disruption, finding powerful examples. These include the case of Nikki Catsouras, who died in a car crash in 2006. Gruesome photographs were leaked on to the web and later seen by her parents. Anonymous web users also forwarded the images to family members, along with cruel messages. On camera, Nikki's mother says she believes that the internet is a literal embodiment of the Antichrist.

There is a sharp contrast between such stories and those emphasising the power of tech to help us advance. For instance, two neuroscientists enthuse about the potential for “tweeting thoughts” via a brain-reading device. One giggles as he imagines it.

And there are many memorable moments to marvel at. Take, for example, entrepreneur Elon Musk, whose company Tesla helped bring electric vehicles into mass production. He is filmed for what seems like minutes, staring pensively and childlike at the desk in front of him, before finally answering a question about his dreams: “I only remember the nightmares,” he says.

“The internet changed all our lives; it might change them all again, were it to ever disappear”

And apropos of dreaming, Herzog asks several of his interviewees whether they think the internet could develop some kind of consciousness: could it, for example, dream? It's a question as naive as the film-maker, but it's supposed to be. The query produces completely different answers from everyone, all interesting. Silicon Valley

pioneer Danny Hillis, for one, suggests that the internet may already be self-aware. It simply might not have told us.

The most powerful implication, though, is that while the internet has changed us irrevocably, it is also threatened by forces that might switch it off, light-bulb-like, in an instant. Could an unusually large solar storm cause a geomagnetic disturbance powerful enough to knock out the World Wide Web? The Carrington Event of 1859, which caused sparks to fly out of telegraph equipment, indicates this is at least possible.

Lingering in Herzog's meandering tour is this unimaginable scenario: just as the internet appeared without warning and changed all our lives, it might change them all again if it ever disappeared. We, Herzog suggests, continue to be at its mercy at every turn. ■

Chris Baraniuk is a writer based in London



A SCENE FROM LO AND BEHOLD. PHOTO COURTESY OF MAGNOLIA PICTURES

For good or ill, the internet has disrupted the lives of everyone



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The successful candidate must present credentials that justify an appointment at the assistant-professor level, including a Ph.D. (or equivalent degree) in AMO physics or a related discipline, and should demonstrate a strong commitment to teaching and mentoring students at all levels and to serving a diverse population. Applications, including a cover letter, CV, and statements of research and teaching interests along with a list of references should be submitted to: <http://careers.k-state.edu/cw/en-us/job/497698/assistant-professor-in-theoretical-ultrafast-amo-physics>.

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Berkeley

Department of Chemistry
UNIVERSITY OF CALIFORNIA Faculty Position in Chemistry

The Department of Chemistry, at the University of California, Berkeley, invites applications for one faculty position at the assistant professor level with an expected start date of July 1, 2017. Preference will be given to candidates in the broadly defined fields of inorganic and/or materials chemistry. However, we will consider creative and energetic candidates who show extraordinary promise or accomplishment in research and teaching in any area of chemistry. The basic qualification for this position is a Ph.D. or equivalent degree in chemistry or a related field at the time of application.

All applicants should submit their most recently updated curriculum vitae and a statement of research and provide at least three but no more than five letters of recommendation. A cover letter and a statement of teaching are optional. Applications should be submitted electronically through our web-based system at: <https://aprecruit.berkeley.edu/apply/JPF01131>.

All recommendation letters will be treated as confidential per University of California policy and California state law. Please refer potential referees, including when letters are provided via a third party (i.e., dossier service or career center), to the UC statement on confidentiality (<http://apo.berkeley.edu/evalltr.html>) prior to submitting their letters.

The deadline for receipt of application material is November 1, 2016. Please direct questions to Lauren Nakashima (lnakashima@berkeley.edu).

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Northeastern

Search for Faculty Position in Immunology of Host-Microbial Interactions Open Rank

Search Committee: Javier Apfeld, Slava Epstein, Veronica Godoy-Carter (Committee Chair), Konstantin Khrapko, and Misha Sitkovsky. The Department of Biology at Northeastern University, Boston, Massachusetts invites applications for a junior tenure-track or senior tenured faculty position in the general area of the immunology of host-microbial interactions. Applications from established investigators are encouraged. Rank will be commensurate with experience.

We are seeking innovative, creative and collaborative individuals who will develop a vibrant research program in areas such as interactions between the immune system and pathogenic organisms, or/and interactions between the host and its microbiome. Priority will be placed on individuals whose research interests synergize with the department's strengths in immunology and molecular microbiology. The successful candidate will be expected to direct a strong extramurally-funded research program, teach undergraduate and graduate courses, and participate in departmental, college and university service. Review of applications will begin immediately and continue until the position is filled. The anticipated start date is Fall Semester, 2017.

The Department of Biology is strongly interdisciplinary, with 20 tenured and tenure-track faculty in Biology and an additional 9 faculty with joint appointments in other departments. The department administers programs in the College of Science at Northeastern University in Biology, Cell and Molecular Biology, Biochemistry, and Behavioral Neuroscience for 1,200 undergraduates. It hosts 100 students in Ph.D., Masters, and Professional Masters programs. The Department is affiliated with the Antimicrobial Discovery Center, the New England Inflammation and Tissue Protection Institute, and the Marine Science Center in Nahant, Massachusetts. Northeastern University occupies a vibrant 67-acre campus in the heart of Boston, surrounded by other leading educational, health care, technological, and research institutions, as well as world-renowned art and music venues (www.northeastern.edu/biology/).

Qualifications

Applicants must have a PhD in the biological sciences or another closely related discipline prior to the start of the appointment, pertinent postdoctoral research experience, and a strong record of scholarly accomplishment commensurate with the appointment rank. Qualified candidates must have experience in, or a demonstrated commitment to, working with diverse student populations and/or in a culturally diverse work and educational environment.

Additional Information:

A complete application includes a cover letter, curriculum vitae, research statement, teaching statement, and a list of at least three references. Letters of reference will be requested at a later stage. Apply on-line at: <https://neu.peopleadmin.com/postings/44726>

For informal inquiries contact
Dr. Veronica Godoy-Carter,
via e-mail at biojobs@northeastern.edu.

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EDITOR'S PICK



Reasons to be fracky, part one

From Richard Smithson

Michael Le Page argues the UK has no good reason to approve fracking (15 October, p 21). One good reason is that domestic production from the North Sea (which provides 43 per cent of our gas) is almost certain to decline.

Another is that the devaluation of the pound makes imported gas more expensive. Yet another reason is that Russia, which supplies 33 per cent of Europe's gas, is engaged in a strategy to destabilise Europe. This is succeeding, for example by increasing the flow of refugees and other migrants from the Middle East.

Russia's leverage on Europe is increased by our dependence on Russian gas. No responsible European government can ignore this strategy.

An increase in domestic production is a prudent step. There is no reason why it should increase our overall gas use. Compared with other fossil fuel extraction, fracking has a small impact on the environment.

Although it is important to reduce our use of fossil fuels, reducing gas use is problematic. This is partly because so many households rely on it for heating. *Cockermouth, Cumbria, UK*

To read more letters, visit newscientist.com/letters

Cracking methane past and present

From Aart Heesterman

Jon Cartwright suggests cracking methane into hydrogen and carbon soot might make it economical to continue to use fossil fuels without causing carbon dioxide emissions (8 October, p 28). This is unlikely to change the world. Expending energy on cracking methane and then using the hydrogen, while disposing of the soot and its energy content, is poor energy efficiency.

Cartwright also asserts that renewables are unreliable and production of hydrogen by electrolysis of water is too costly. The PEM proton-exchange electrolysis unit at Energiepark Mainz in Germany is designed to ensure a more even energy supply by converting surplus electricity from wind farms to hydrogen.

Other relevant innovations include long-distance high-voltage direct current electricity transmission and cost-effective salt-based batteries.

One obvious use for the hydrogen produced in Mainz is to react it with carbon dioxide into synthetic methane, to be used as gas or processed further into liquid hydrocarbon compounds. *Birmingham, UK*

From Ray Carnally

The story of methane-cracking reminded me of an experiment I carried out when I spent six months at the British Iron and Steel Research Association in Sheffield in about 1970. North Sea oil and gas were new and exciting.

I was tasked with designing and building apparatus to pass methane gas through molten iron to increase the metal's carbon content for production of steel. The fun part was turning on the methane flow and seeing the quartz viewport window turn instantly black from the clouds of carbon released.

In another iteration of the experiment, we used a bundle of 6-metre gas tubes. Four or five of us would hold it on our shoulders and feed it into an electric arc furnace, watching the furious reaction. As the tubes melted we walked closer until the last of us had to move away as their lab coat scorched.

What a pity we were focused so much on the carbon and did not consider what could be done with the hydrogen.

Christchurch, Dorset, UK

Spinal repair is a worthy goal

From Toby Pereira

Talk of so-called head transplants seems premature (24 September, p 8). The real news is that we may be nearing the point where it is possible to repair a damaged spinal cord, giving movement to people we previously thought were paralysed for life. That would be one of the biggest medical breakthroughs of all time: but as you report, the evidence is very much in doubt.

Given this, transplanting a whole body onto someone's head is little more than speculation at present. It is interesting, but really warrants just a sentence about potential future applications once spinal cord repair is achieved.

Rayne, Essex, UK

Utopia doesn't have to be a city

From Keith Bremner

All the definitions of a utopian society that Philip Ball describes assume a structure similar to European societies of the past 3000 years or so (17 September, p 44). People live in houses, work and grow their food.

That work is always going to be a source of conflict. The division of labour is a self-destructive part

of the definition. No one seems to consider hunter-gatherer societies, such as those of Australia before the arrival of the first fleet of British convicts in 1788. Nature provided food without much or any work. They kept their numbers low: estimates vary from 1 to 2 million on the continent for something like 40,000 years.

We might just get another chance at utopia if we manage to develop robots to work for us... *Brisbane, Queensland, Australia*

Testing hypotheses and being human

From Christine McNulty

Diana Kwon discusses our brains making predictions to test against incoming data (1 October, p 30). This reminded me of a chat with the late, great neuropsychologist Richard Gregory.

He believed that the survival of our proto-human ancestors depended on their drive to abandon the constraints of "instinct" in which sense data drive behaviour directly. Volitional behaviour was more energetically efficient. So humans must construct falsifiable hypotheses, in order that testing them can resolve the ambiguity inherent in our perceptions. Non-human animals, he believed, experience no such ambiguity. *Oxhey, Hertfordshire, UK*

Contributing to brain research

From Jean Gibbs

Congratulations on a truly revealing story about brains donated to science (24 September, p 46). In 2002, we donated my husband's brain to Neville Butler's research at the University of Bristol. I was told that he had had Alzheimer's disease, but had no idea of the process – until now. Everyone who wants to do

“So, not only are they terrorising me, they’re also eavesdropping too.”

Sarah Moore responds to news that spiders can hear her walking and talking from across the room (22 October, p 16).

something positive for brain research should read this.
Swanage, Dorset, UK

Friends in the eye of the beholder

From John Darlington

So unattractive friends may make you more fanciable (8 October, p 7). Back in the 1970s, when we went to dances, I always went with the same “less good-looking” friend. I recently confessed this to a mutual acquaintance, feeling a twinge of guilt about it. He said: “Don’t feel too bad, he always said he went with you for exactly the same reason.”

Drumsna, County Leitrim, Ireland

Synthetic bacteria in horror fiction

From Ian Gordon

I was interested to read Ricard Solé’s proposal to use synthetic bacteria to perform various environmental tasks for us

(1 October, p 36). They could be used to deal with our mountains of waste plastic – a desirable aim.

I find myself, however, thinking back to a 1970 episode of the UK television series *Doomwatch*, and the 1971 book *Mutant 59: The Plastic Eaters* by Kit Pedler and Gerry Davis. Both explore the unexpected consequences of such a synthetic bacterium mutating to consume plastics other than those against which it was targeted.

The film *The Andromeda Strain* (reviewed 1 July 1971, p 43) borrowed the trope of a plane falling out of the sky as the plastic on board dissolved. I feel these must be mandatory reading and viewing for anyone proposing to engineer and release such a microorganism.
Camberley, Surrey, UK

Why have a robot take you walkies?

From Andy Green

Brian Horton suggests a CareBot for the elderly that follows you when you go for a walk and guides

you home when you get lost (Letters, 24 September).

Isn’t that what dogs are for?
London, UK

Self-citation and other-citation

From Terence Kuch

Feedback recalls a study in the early 1970s finding that the more citations an academic’s papers received, the higher he or she got on the academic ladder, but that the correlation disappeared when self-citations were ignored (10 September).

My 1970s thesis for American University looked at 100 consecutive issues of the *American Journal of Physiology*. It showed that self-citers were significantly more often cited by others than those who avoided this self-promotion.

There is a possible simple cause for this. Self-citers typically had published more citable papers than had those who didn’t cite themselves.

Pimmit Hills, Virginia, US

Santa is coming to town, and going

From Crad Allerton

Donald Windsor suggests that like Schrödinger’s famous cat, God simultaneously exists and does not exist (Letters, 8 October). The day before reading this I was thinking about the reasons we tell lies. The name of Father Christmas came up – when do you tell your child he doesn’t really exist?

Do we then have an early opportunity to talk with children about Schrödinger’s cat?
Calverton, Buckinghamshire, UK

How many speak Hebrew first?

From Eric Kvaalen

There may be 9 million people who can speak Hebrew to some extent, but not as their first language (8 October, p 5). There are only about 4 million Israeli Jews for whom Hebrew is their native tongue, and very few others for whom that is the case.

Les Essarts-le-Roi, France

For the record

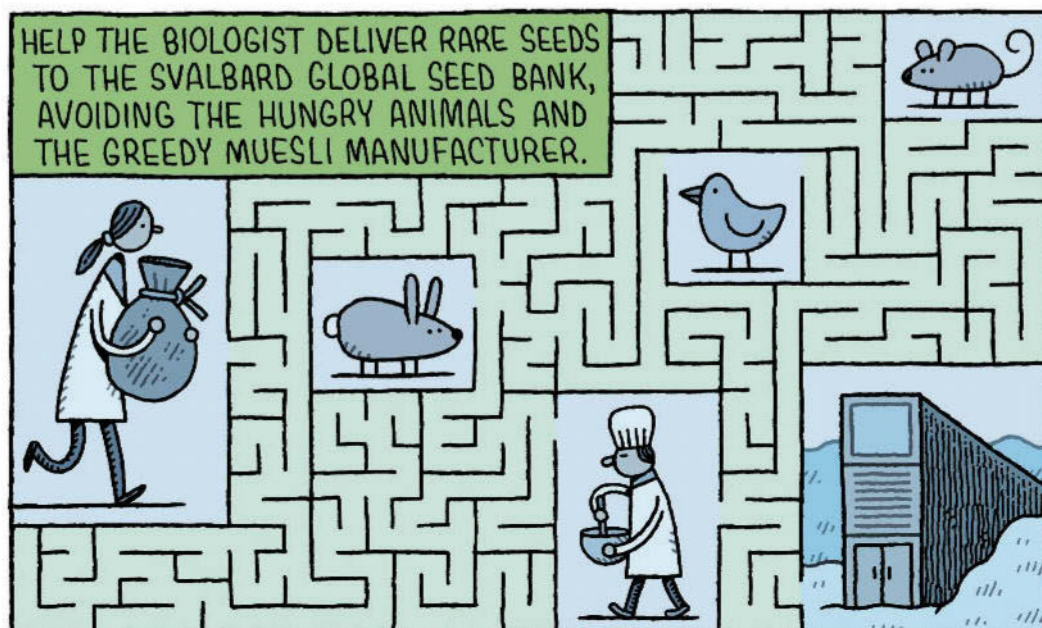
■ Sundrop Farm produces 15,000 tonnes of tomatoes a year using a solar tower 127 metres high to desalinate water piped 5.5 kilometres from the sea (15 October, p 5).

■ The assertion by Soviet botanist Nikolai Vavilov that “biological synthesis is becoming as much a reality as chemical” was his own (15 October, p 44).

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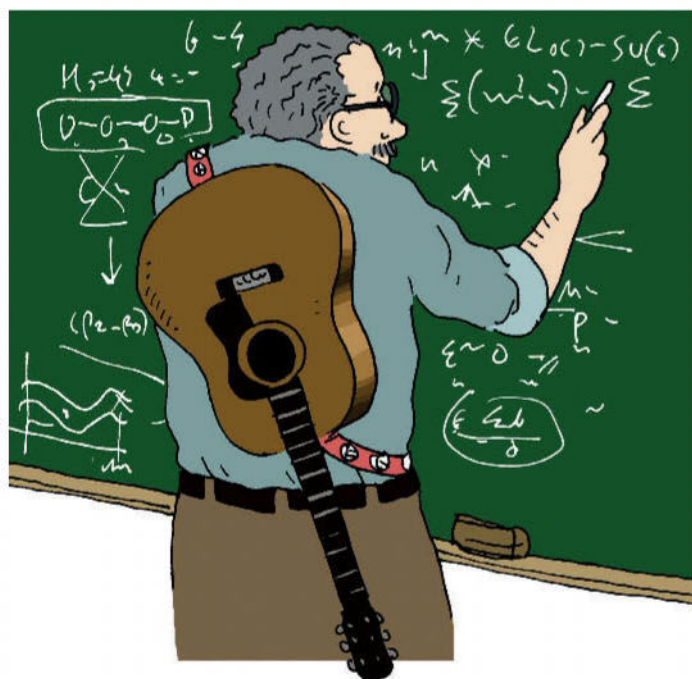
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AUTHORITIES in Sweden, perhaps feeling that 2016 hasn't been strange enough already, have awarded this year's Nobel Prize in Literature to Bob Dylan. But maybe we shouldn't be so surprised.

Last year, a team at the Karolinska Institute in Sweden discovered more than 727 references to his music in the scientific literature. There is "The CRISPRs, they are a-changin': how prokaryotes generate adaptive immunity" and "Blowin' in the wind: both 'negative' and 'positive' feedback in an obscured high-z quasar".

In fact, in 2014, five scientists at the Karolinska divulged their longstanding bet to see who could sneak the most Dylan references into their work.

However, Dylan isn't the king of sci-lit references. In a new unpublished paper, Ger Rijkers at the University College Roosevelt in the Netherlands and his colleagues found 211 publications since 1990 citing Dylan in their titles, but no less than

589 papers referenced the Beatles, with titles such as "I get height with a little help from my friends: herd protection from sanitation on child growth in rural Ecuador".

But which musical icon will future researchers draw inspiration from? Feedback awaits your discoveries of lyrics from more contemporary artists lurking in the scientific literature.

PREVIOUSLY, Feedback wondered why so many of those discussing Britain's post-European Union fortunes at the Conservative party conference were preoccupied with food (15 October).

Now the national conversation has shifted to the threat Brexit poses to our supply of Marmite, the black, yeast-based spread whose sharply divisive flavour makes a fitting analogy for these post-referendum days.

Thankfully, our elected representatives are working hard to establish cohesion: one

Conservative councillor has launched a campaign to make supporting the EU illegal. Christian Holliday is petitioning Parliament to amend the 1848 Treason Felony Act so those who "imagine, devise, promote, work, or encourage others, to support the UK becoming a member of the European Union" could be jailed for life.

If enacted, this change could mean that scientists hoping to secure their EU-funded grants would risk being plucked from their ivory towers and thrown into the Tower of London by Councillor Holliday's beefeaters. But with our Marmite supply in jeopardy, don't we need them now more than ever to create those sought after innovative jams?

THE DIVINE Steve Morris sends us a truly exceptional case of nominative determinism involving a US businesswoman and "Democratic strategist" who offered her insights as a co-host of MSNBC's afternoon news show *The Cycle*. Here's looking at you, Krystal Ball.

PEDRO SARAIVA chances upon news of a lesser-known hormone secreted by the pineal gland. MetatoninResearch.org tells us that this chemical is a "higher octave" version of the timekeeping hormone melatonin, and "modifies the borders of consciousness by temporarily reprogramming our brain circuitry in a unique way". Such unbounded action might be explained by one of Metatonin's main components: the powerful hallucinogen DMT.

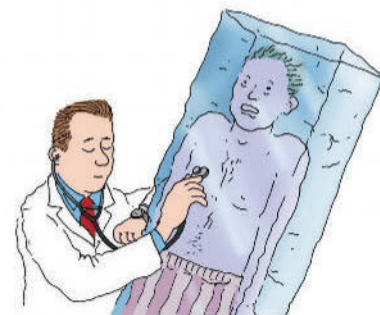
The authors note that "higher intelligence and consciousness exists at the quantum-entangled time transcendent holographic infinitely intelligent universal macro-micro all-pervasive level. Humans exist on a limited mental/physical single-track time-space macro level". Sadly, this potential avenue of research will remain unexplored by scientists seconded to produce

innovative jams, unless they come up with a DMT-based breakfast spread.

AN EPIDEMIC of scary clown sightings has been terrifying the public both here and abroad (15 October, p 5), leading the professional variety to complain that their craft is being vilified. Finally then, some news that may turn those grease-painted frowns upside down.

A colleague tells us that the latest issue of the *Journal of Paediatrics and Child Health* reports on "the effectiveness of pre-operative clown intervention on psychological distress". After compiling eight studies, researchers found that clowns are almost always less distressing to children than pondering imminent surgery. A victory, of sorts?

WHAT kind of life-extending techniques are doctors using in New Zealand? While checking



the clinic attendance records at his hospital, Martin Necas was informed by computer: "Sorry, cannot check whether this patient is frozen."

A SIGN on the highway tells Penny Jackson: "Picking up your litter puts roadworkers lives at risk".

"It took me a while to work out why they wanted me to save lives by leaving it on the ground," she says.

Fred Nind sends word of Illumibowl, a gadget that will light up your toilet at night. He says "I rather like the fact that the device is described as 'motion activated'."

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

Ant hill mob

While mowing the grass, I noticed that in several places ant nests were situated under clumps of daisies. Do the ants choose to nest under daisies, or do these flowers grow where they do because of the ants' activity?

■ Numerous ant species collect seeds, in many cases for food, as in the case of harvester ants in North American deserts. Many plants have exploited this seed-collecting behaviour and use ants as dispersal agents, having evolved seed appendages called elaiosomes that are rich in lipids and minerals. Elaiosomes act to attract and reward ants for transport, much as the fleshy pulp of fruit aids seed dispersal by birds.

Ants rarely carry seeds far, but seeds still benefit from ants moving them because they often become buried in shallow, nutrient-rich patches of soil.

Ants in both Australia and Europe have been found to collect daisy seeds and take them to their nests. However, the reason for this remains unclear. Daisy seeds seem to provide no elaiosomes as a reward, so it's possible that ants may be collecting the seed itself as food. Even in this case, dispersal may occur because ants do not always consume the whole seed. As a result, daisy seeds may germinate and give rise to plants on and around the ant nest. This seems the likely scenario described by your correspondent. *Philip Hulme*
Christchurch, New Zealand

■ Ants nest underground and construct an extensive network of tunnels. They will make use of any plant with a suitable root system, probably because it is easier to run along a root than walls of loose soil.

Incidentally, the loosening of soil by insects makes it easier to remove lawn weeds – daisy roots being as hard as boots to pull up!

Richard Lucas
Hawley, Hampshire, UK

Richard Lucas refers to Cockney rhyming slang in his reply – daisy roots being slang for boots. This was popularised in the song My Old Man's a Dustman by Lonnie Donegan, which contains the following line about heavy boots: "He's got such a job to pull them off that he calls them daisy roots." – Ed

Snore flaw

I snore. My wife snores. Our cat snores. Next door's dog snores. I've heard zoo animals snore. Revealing your position to every predator within earshot when you are vulnerable has got to be a bad idea. But we don't snore all the time, so it's not an unavoidable activity like breathing. So why hasn't evolution eliminated snoring?

■ Your correspondent's list of snorers is revealing: the wolves and wildcats that humans domesticated into dogs and cats are at the top of the food chain, with essentially no natural predation. In any case, humans and domesticated animals do not suffer such strong selection

pressures as wild animals because they live in a safe, modified environment. "Zoo animals" presumably refers to mammals, such as bears or lions, but these are poor examples because they may be fatter than wild counterparts, so more likely to snore – though snoring has been poorly documented in the wild.

Only mammals can snore in the strictest sense. Snoring is the sound of membranous, loosely

"Snorers in herds may have a selective advantage, sleeping soundly while the rest are disturbed"

supported tissues – such as the tongue, soft palate and tonsils – vibrating in the upper airways when relaxed during sleep. There may be a genetic component, because the likelihood of snoring increases with heritable features such as a large tongue or a receding chin, but many non-heritable lifestyle traits, such as obesity, smoking and alcohol consumption, also make it more likely, particularly through the constriction of airways.

In humans, even if snoring is heritable, it may not face strong selective pressure because it is more prevalent after the age of 65 or so. Snorers in a group of early human hunter-gatherers were therefore more likely to be of post-reproductive age, so being picked off by predators wouldn't have stopped their "snoring genes" from being passed on.

If snoring does persist in the

wild, this suggests it is not as maladaptive as your correspondent fears.

Sam Buckton
Cambridge, UK

■ Your soft palate can vibrate when you breathe during sleep, resulting in snoring. This can be exacerbated by excess fat or a hereditary predisposition. The genes that cause this have been passed down through generations, so you might think they must have a positive, or at least a neutral, effect on genetic fitness. If any genetic propensity for snoring had a negative effect, it should be eliminated from the population over time.

The tendency for pack or herd animals to snore loudly may have an advantage, with the snorers sleeping soundly while the rest have their sleep disturbed. The next day, the snorers may be more refreshed than those that had a bad night and thus more likely to be successful in the evolutionary competition of natural selection.

David Muir
Edinburgh, UK

This week's question

MILK'S MUCKY MASS

My sister claims to know when milk has gone off because "the carton feels heavier than it should". Could she be right? And if so, why?

Birte Nielsen
Paris, France

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November 11- 13, 2016.

oSTEM is a society dedicated to educating and fostering leadership opportunities for LGBTQA students in STEM fields with chapters at colleges and universities across the country.

The conference is three days of LGBTQA & STEM speakers, panels, workshops, and discussions on STEM, LGBTQ topics, and the intersections between them.

Registration is still open until October 21st.

For more information visit oSTEM.org/register or email conference@ostem.org



#oSTEM2016